Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

1010 EMPIRE BUILDING | OCTOBER, 1942 | PITTSBURGH, PA.

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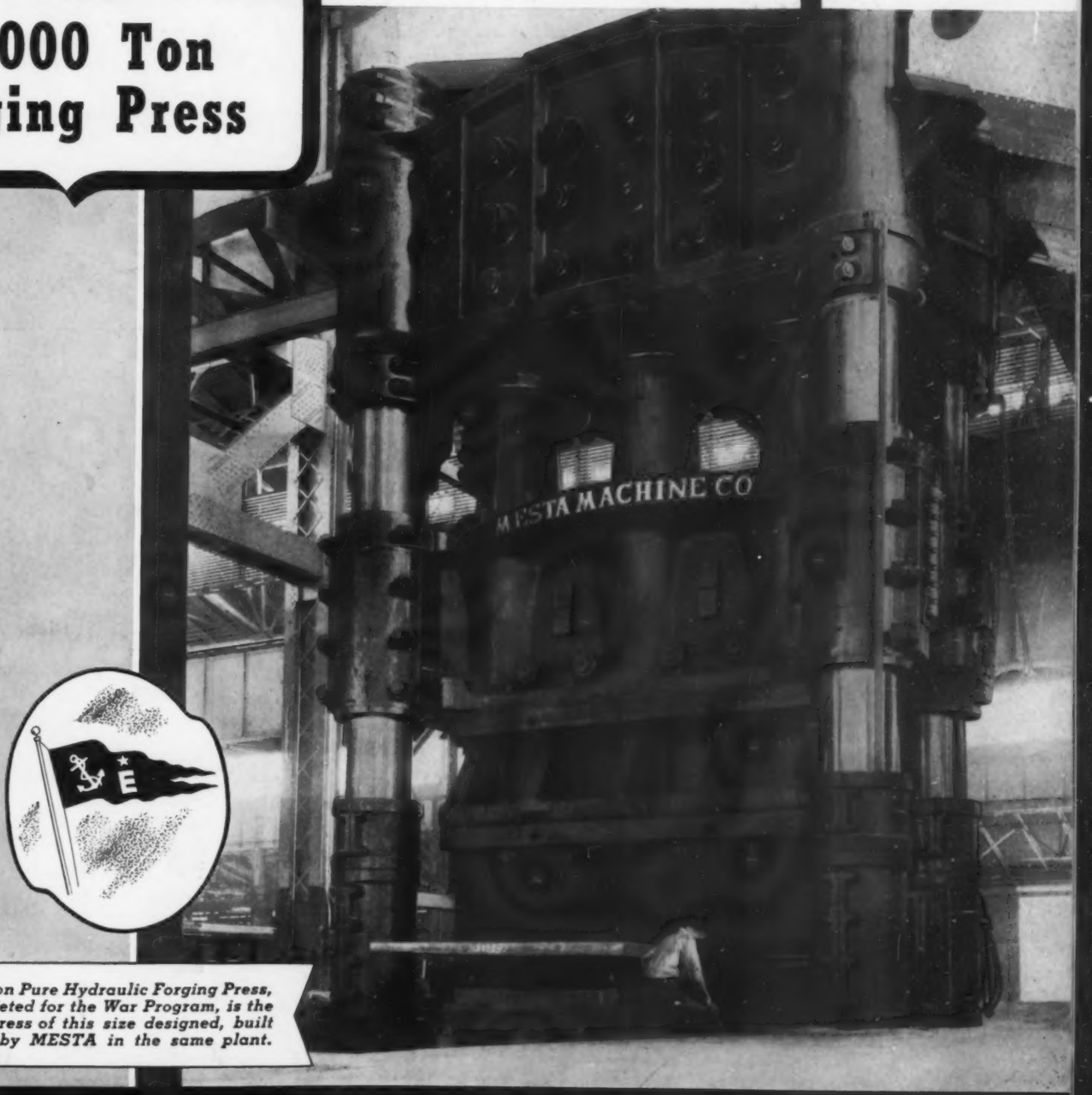
NOV 3 1942
DETROIT

MESTA
14,000 Ton Forging Press



This 14,000 Ton Pure Hydraulic Forging Press, recently completed for the War Program, is the second huge press of this size designed, built and installed by MESTA in the same plant.

MESTA MACHINE COMPANY . . PITTSBURGH, PA.

With Speed, Space and Production the cry—

Let the Modern UNITROL

REG. U.S. PAT. OFF.

method of housing and *centralizing* Motor Control help solve vital production problems

Unitrol, a simpler, better way of housing Motor Control whether inside a machine, beside a machine, or in a centralized group . . . eliminates many of the operations, interruptions, and obstacles that stand between America and the production it must have.

If you are manufacturing important motorized machines with built-in control, Unitrol speeds up that process by eliminating any need for inside mounting bases, by eliminating many other machining, wiring and assembling operations.

If you have installed or are going to install Motor Control near a group of machines, Unitrol packs Motor Control into a much smaller space, enables you to move Motor Control out of the way, to utilize space otherwise wasted. It eliminates any need for special floor or wall preparation, saves many vital man-hours, conserves vital space.

If you are centralizing Motor Control for an entire plant, Unitrol enables you to do it better, faster, easier, far more economically . . . It enables you to get more than double the amount of control in the same space . . . It enables you to *adapt* your control to the space you have without further preparation or building expense. It expands and contracts easily, to follow your changing requirements.

No man concerned with the mounting, installation, use or maintenance of Motor Control; no man concerned with motorized machine production, can afford to overlook Unitrol. The whole story is told in the book "Unitrol . . . the next step forward in Motor Control progress." It's free for the asking. But write *today—now*—for your copy. CUTLER-HAMMER, Inc., 1269 St. Paul Avenue, Milwaukee, Wis. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto.

← The individual Unitrol mounting frame is *better* for machines with built-in Motor Control. It eliminates many machining, wiring and assembling operations.

→ The individual Unitrol *Section* houses Motor Control for several motors or motorized machines, is compact, space-saving, convenient and economical. No supports, no other structures or preparation necessary.

The complete Unitrol Control Center houses all the control and control equipment in the plant, for easy, speedy man-power-saving installation, maintenance, change, expansion or curtailment. No wall or floor preparation. No racks, trellises or frames. Permits installation of more than double as much control in same space.

CUTLER-HAMMER
UNITROL
C-H

Copyright 1942—Cutler-Hammer, Inc.

1892-1942 50th ANNIVERSARY

All the features you need for *better* switch engine headlighting

Pyle-National Type 14055 switch engine headlight case was designed especially to meet the needs of yard engine and switching service. The case design is compact, to minimize the chance of damage from overhanging loads, yet the case is of substantial cast metal construction and has a full size 14 inch reflector. The light beam is considerably wider than that of a standard locomotive headlight, to spread the light, ideally meeting the needs of mill and industrial service. The edge-mounted reflector and watertight sealed construction assure full protection to reflector and case interior. Type 14055 is available for either base or back mounting. Plain or numeral visors can be furnished.

★

With base mounting feet and numeral visor

With back attachment mounting lugs

With base mounting feet and short visor

THE PYLE-NATIONAL COMPANY
1334-58 North Kostner Avenue • Chicago, Illinois
Offices: New York · Baltimore · Pittsburgh · St. Louis
St. Paul · San Francisco

PYLE-NATIONAL
ELECTRICAL EQUIPMENT
• SINCE 1897 •

CONDUIT FITTINGS • FLOODLIGHT PROJECTORS • LOCOMOTIVE ELECTRICAL EQUIPMENT

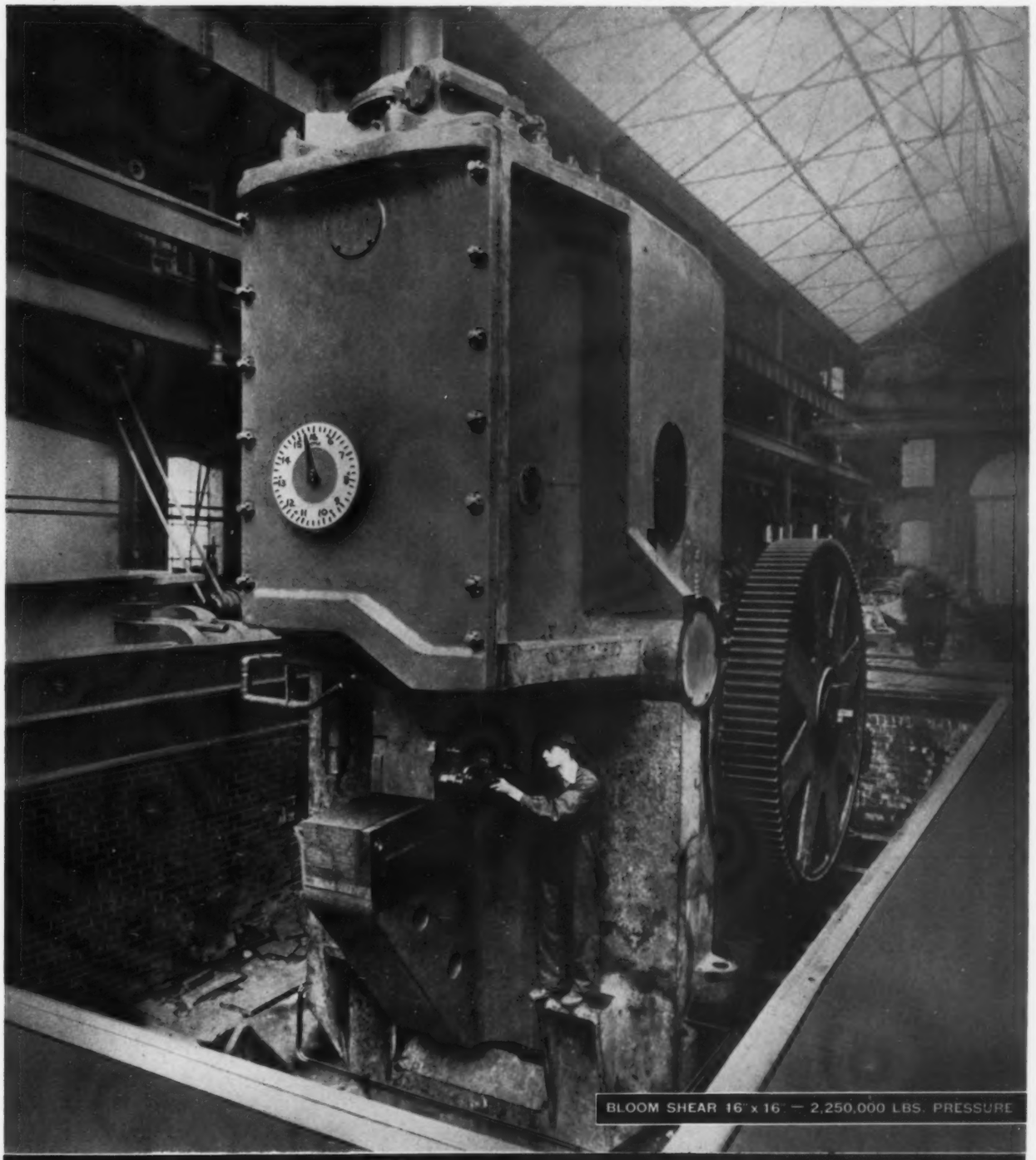
A modern 15-ton, 120-foot span all-welded mill-type crane. One of 15 duplicate cranes on one order.
Hundreds of Cleveland all-weldeds are serving the tough jobs in steel mills. They will be found in nearly every modern mill built in recent years.

THE CLEVELAND CRANE & ENGINEERING CO.

1131 EAST 283 RD ST. WICKLIFFE, OHIO

CLEVELAND CRANES

MODERN ALL-WELDED STEEL MILL CRANES



HYDROPRESS · INC.

ENGINEERS CONTRACTORS

HYDRAULIC PRESSES · ROLLING MILLS
PUMPS · ACCUMULATORS

570 LEXINGTON AVENUE • NEW YORK • N. Y.

FOR *HOT* METAL APPLICATIONS

EC&M CONTROL

offers

MANY ADVANTAGES

● 175-Ton Hot Metal Holding Ladle built by Treadwell Construction Co., Midland, Pa.

★ Wherever hot metal is stored, handled or processed, many firms, acquainted with EC&M value, select this quality apparatus because of their confidence in it—in the engineering and experience which it represents.

Typical hot metal applications include: (1) Ladle Cranes, (2) Hot Metal Cranes, (3) Hot Metal Mixers, (4) Bessemer Converters, (5) Storage Vessels, (6) Blast Furnace Guns—where only tried and true equipment which represents the utmost in safety and dependability is acceptable.

Listed at the left are a few of the EC&M products especially designed for the requirements of hot metal service. They have proved themselves highly successful in many applications throughout the years. Specify EC&M Control for hot metal applications.

● EC&M Air and Magnetically-operated Type WB Brake—normally operated by motor current with air-release for emergency operation.

EC&M EQUIPMENT
Especially Designed for Hot Metal Service

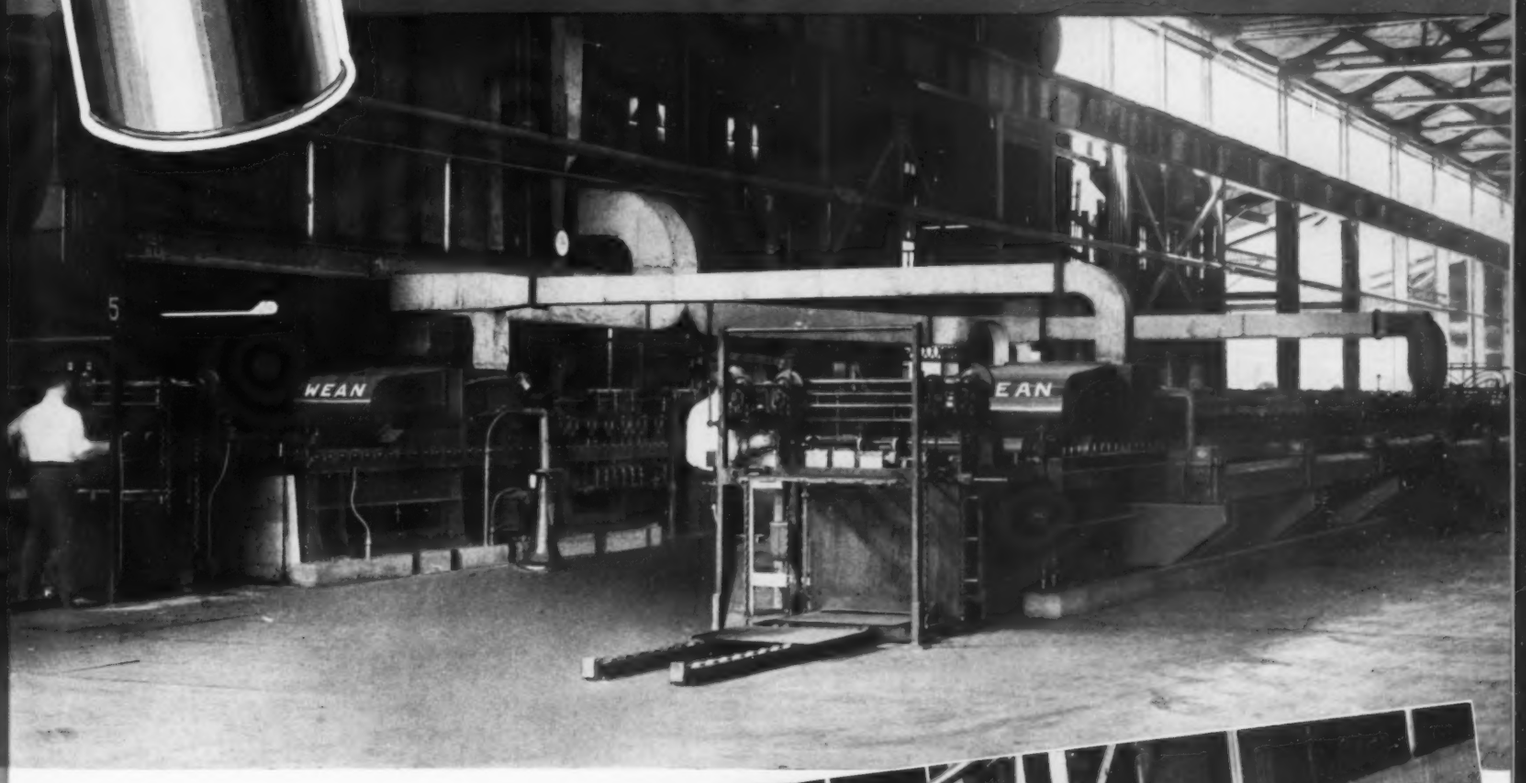
1. EC&M Converter Control System (Patent No. 1,899,586)
2. Dead-Man's Master Switch
3. Air and Magnetically-released Brakes
4. Positive-type Limit Stops for Slowdown and Final Stopping
5. LINE-ARC Magnetic Contactor Controllers.

THE ELECTRIC CONTROLLER & MFG. CO.
2700 E. 79th ST. CLEVELAND, OHIO

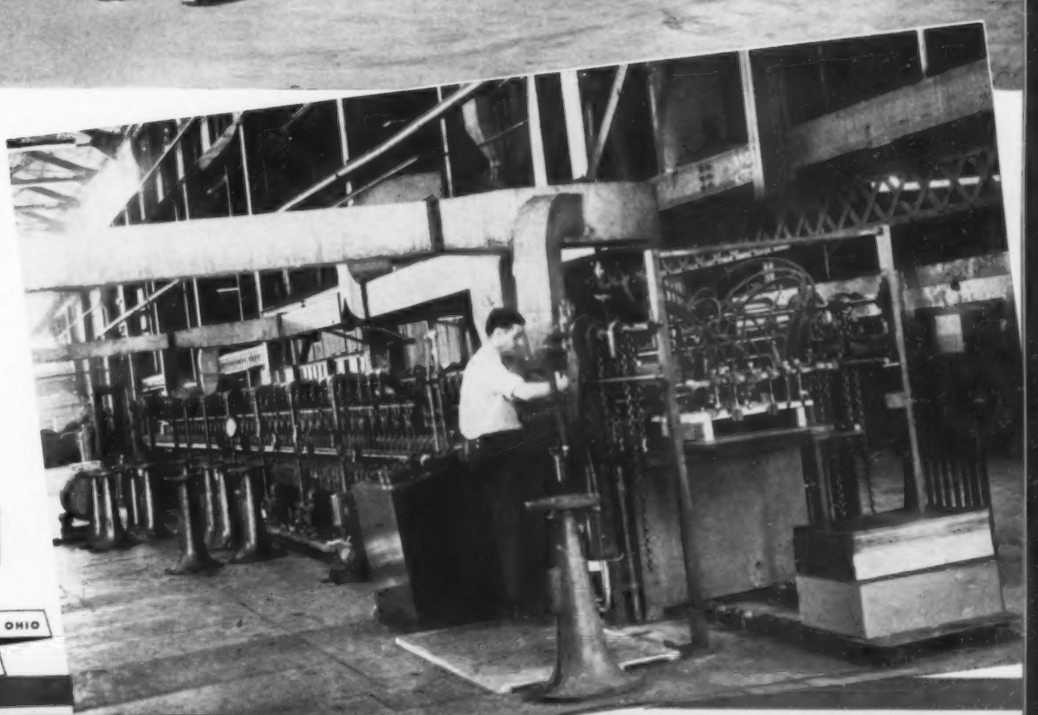
Tin Plate BONDERIZING EQUIPMENT

Light gauge steel used for containers is often called tin plate, whether it is coated or not.

Bonderizing is a chemical treatment using NO TIN and making a satisfactory product for many types of containers.



Support Fighting Forces–
Buy Gov't BONDS



The WEAN ENGINEERING COMPANY, Inc. • WARREN, OHIO

Subsidiary Company
THE BRODEN CONSTRUCTION CO.

SPECIALISTS IN SHEET, TIN AND STRIP MILL EQUIPMENT

Associated Companies

LEE WILSON ENGINEERING CO.
CLEVELAND, OHIO

THE McKAY MACHINE CO.
YOUNGSTOWN, OHIO

FLINN & DREFFEIN CO.
CHICAGO, ILL.

THE WELLMAN SMITH OWEN ENGR. CORP., LTD.
LONDON, ENGLAND

THE HALLDEN MACHINE CO.
THOMASTON, CONN.

THE WEAN ENGINEERING CO. OF CANADA, LTD.
HAMILTON, ONT.

"Store welding electrodes in a dry place— they will keep indefinitely if properly cared for"

Always keep electrodes in a dry place — on a clean shelf or rack, or at least off the floor. Don't expose them to moisture, keep them away from sweating pipes and open windows. If by accident a box of electrodes should get wet, spread them out to dry immediately.

Follow these simple precautions together with those enumerated at the right — fight waste to speed victory.

A booklet of shop bulletins illustrating "do's" and "dont's" has been prepared to help your welding operators get the most out of every electrode. We'll gladly send you as many copies as you can use.

WELDING ELECTRODES ARE SCARCE

Help Prevent Waste

- Do not bend electrodes unless absolutely necessary
- Use electrodes down to a 2-inch stub
- Fit joints properly before welding
- Make legs of fillet welds equal
- Make the face of fillet welds flat

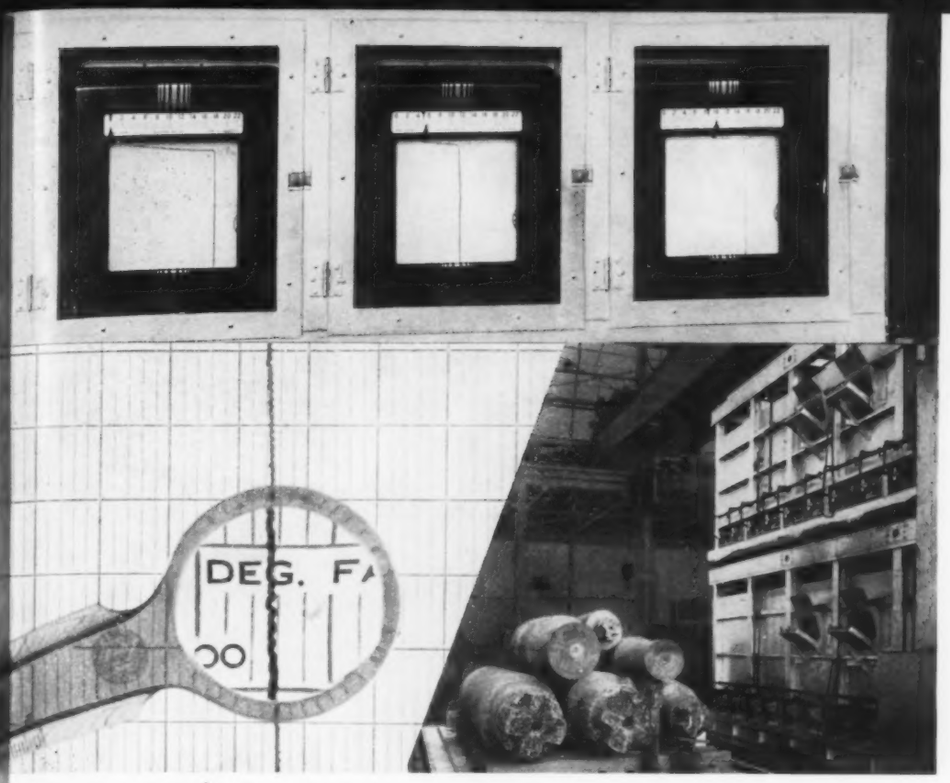
Air Reduction

General Offices:
60 EAST 42nd STREET, NEW YORK, N. Y.
IN TEXAS
MAGNOLIA - AIRCO GAS PRODUCTS CO.

AIRCO

WILSON

OXYGEN IS PRODUCTION — *Don't Waste it!*



Battery of three, two-thermocouple Micromox Pyrometers, and a typical batch of steel rolls annealed under thei r control. Control is so close that couple temperatures are less than 10 degrees apart; as shown by magnified chart section.

WARTIME HEAT-TREATMENT
Magnifies Usefulness of Micromax Control

Heat-treatment of big castings is, of course, no simple matter, even for a concern with the experience of The [redacted] Steel Foundry Co. But this company can, and does, simplify the work by using the most effective heat-treating equipment. They have, for example, recently installed a battery of [redacted] furnace bases, with four Surface Combustion covers, for annealing and heat-treatment of steel rolls.

These big furnaces can follow directions for practically any heating-soaking-cooling cycle, with splendid uniformity. To provide them with the sensitive, dependable automatic direction they need during the two weeks which such a cycle may require, they are equipped with Micromax Electric Control Pyrometers, used in a standard and effective way.

Each furnace has two thermocouples and two fuel-throttling valves, regulated by a single Micromax Controller, which switches from one couple-valve combination to the other at predetermined, regular intervals to equalize the heating throughout the furnace. The instrument, due to its quality of micro-responsiveness, regulates this setup with the utmost precision. It holds temperature at the desired rate, regardless of changes in ambient temperature, fuel pressure, wind direction or any other factor.

And its automatic standardizer, 50-day ink supply, 40-yard chart and freedom from any need for every-day servicing, enable the instrument to run through a complete cycle without a stop and with practically no attention.

For description of the various Micromax models, see Catalog N-33A, 1942, sent on request.

A maker of sheet and tin plate uses these Micromax Electric Control Pyrometers to regulate their annealing furnaces. Here are 3, among several dozen employed in this one plant.

Jrl Ad N-33A-646(2)

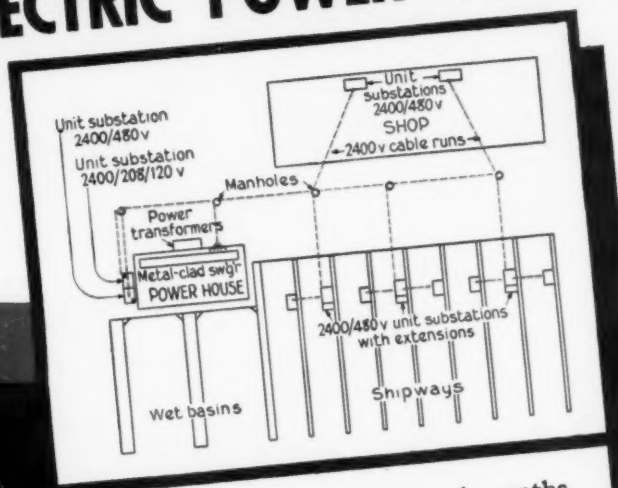
LEEDS & NORTHRUP COMPANY, 4942 STENTON AVE., PHILA., PA.

LEEDS & NORTHRUP

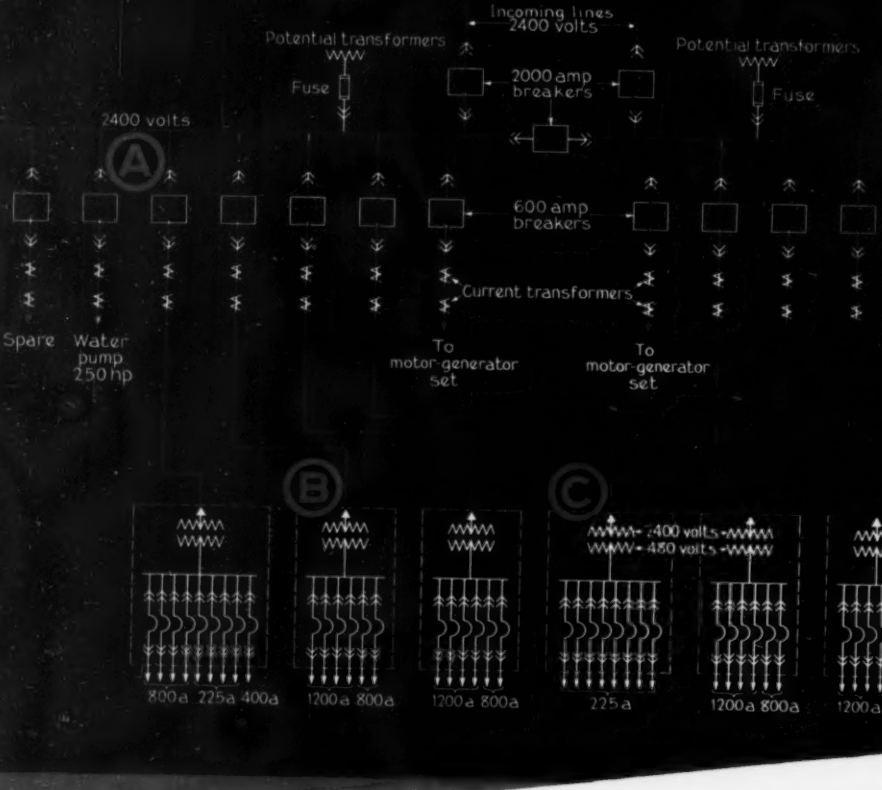
MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

1/4 THE TIME 1/7 THE COPPER

AND A BETTER ELECTRIC POWER SYSTEM



THIS new war plant saved months of time and tons of copper by ordering *standard* power distribution equipments at an early stage of construction—by means of a simple one-line diagram like that below.



Power is distributed at high voltage right to unit substations at the load centers—

—from where it is distributed at 480 volts directly to the loads.

Many war-production factories are ordering plant distribution equipments at an early stage of construction by taking these three simple steps:

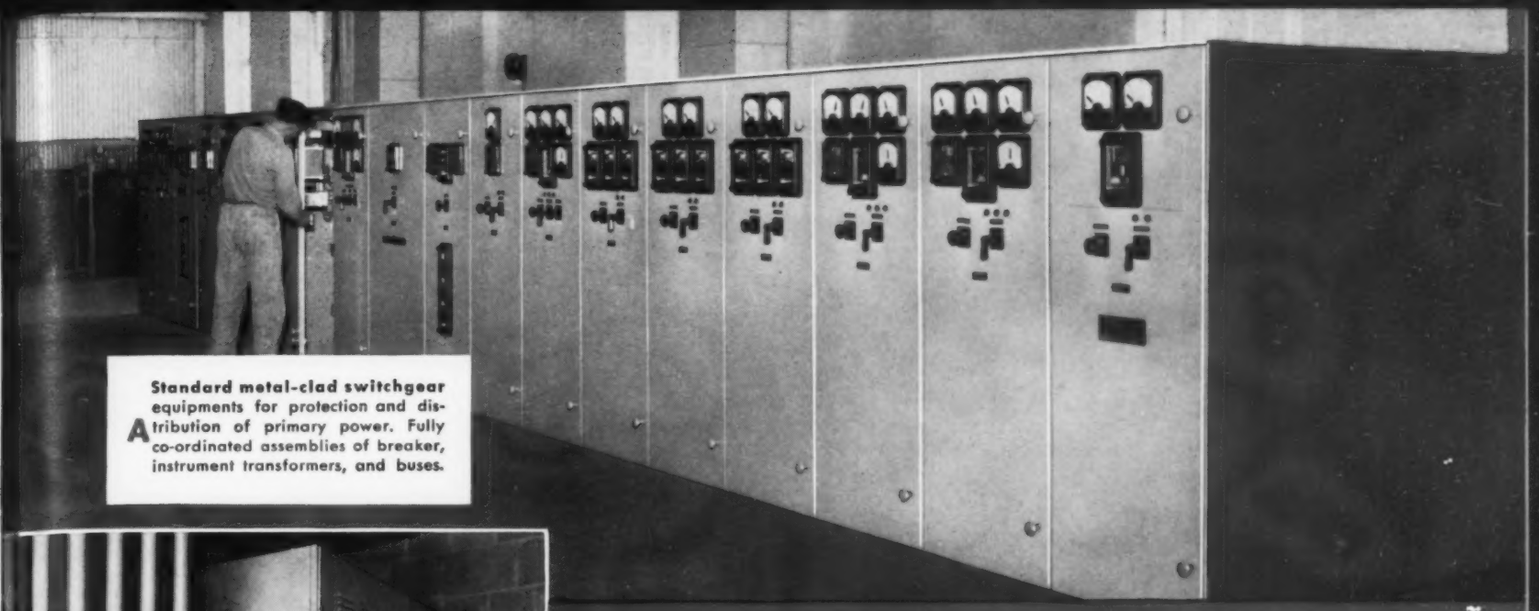
1 *Calculate the total kva you need.* Your consulting engineer can help you to determine this accurately.

2 *Divide the load area into separate load zones of 500, 750, or 1000 kva each.*

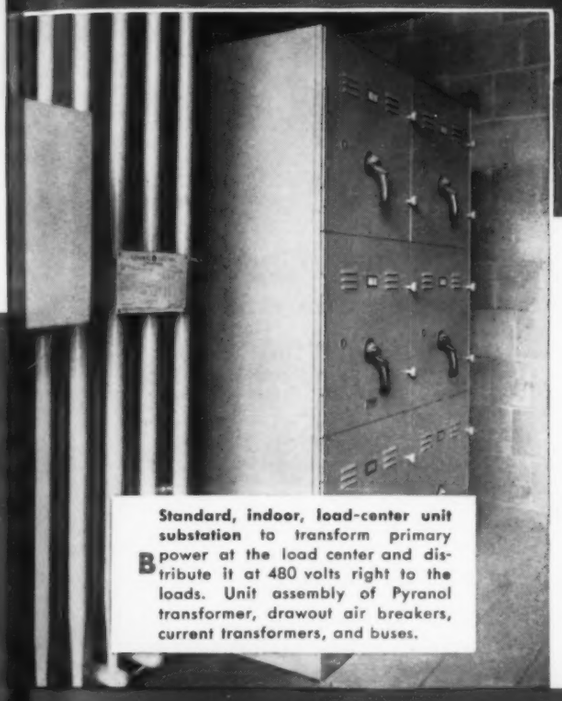
3 *Divide the load of each zone into feeder loads,* and draw a one-line diagram of your proposed load-center system, giving the functions to be performed and the ratings required. *With this one-line diagram you can immediately order standard G-E switchgear equipments and unit substations.*

For further aid, ask for our new bulletin, No. GED-1006.

The Navy "E", for Excellence, has been awarded to 92,780 General Electric employees in six plants manufacturing naval equipment.



A Standard metal-clad switchgear equipments for protection and distribution of primary power. Fully co-ordinated assemblies of breaker, instrument transformers, and buses.



B Standard, indoor, load-center unit substation to transform primary power at the load center and distribute it at 480 volts right to the loads. Unit assembly of Pyranol transformer, drawout air breakers, current transformers, and buses.

MONTHS SAVED BY ORDERING STANDARD EQUIPMENTS

STANDARD G-E load-center power units were ordered for this war plant soon after construction started. A simple one-line diagram like that at the left put our factory right to work. Metal-clad switchgear and unit substations were installed in *one-fourth* the time needed for non-standard, piecemeal assemblies. They were received at the job when needed—all ready to be set in place and connected.

On this page are views of a few of these standard equipments—installed. They are typical of G-E load-center equipments that are being installed quickly and easily in plants everywhere. Note the metal-enclosed construction that safeguards workmen and production.

SAVED 145 TONS OF COPPER WITH LOAD-CENTER POWER DISTRIBUTION

ENGINEERS for this new war plant saved 145 tons of cable copper by taking high-voltage power right to the load centers, as shown at the left. In addition, they got a power distribution system that was so safe and efficient that, when need for additional capacity suddenly arose, they ordered another, a ***duplicate*** system—and saved another 145 tons of copper.

What's more, it took less copper to *build* these standard metal-clad units. The switchgear equipments shown at the top of this page took but 47 pounds of copper each. An open-type, piece-meal assembly would have taken more than four times as much.

If you need electric power for a new, enlarged, or converted war plant, we know you'll be pleased to learn how much copper and other critical materials you can save by using these standard load-center equipments. You'll find, too, that you can get them on the job quickly, and obtain a new high degree of safety and operating dependability. The nearest G-E office is ready to help you. *General Electric, Schenectady, New York.*

C Standard outdoor load-center unit substation to transform and distribute power to outdoor loads.

GENERAL ELECTRIC

★
Award for Excellence
★

ARMY-NAVY PRODUCTION AWARD

for high achievement in the production of war equipment

conferred upon the

LINCOLN ENGINEERING COMPANY

We are proud to announce that we have been awarded the Army and Navy "E"—the coveted emblem conferred by the United States Army and Navy for high achievement in the production of war equipment.

This achievement has resulted from the combined efforts of every man and woman in the employ of the Lincoln Engineering Company. The "E" pin which each person in our organization wears, and the "E" pennant that flies over the Lincoln plant serve as silent inspiration toward greater and greater accomplishment until the time of final and complete Victory.

★

LINCOLN ENGINEERING COMPANY, ST. LOUIS, MO., U. S. A.

Pioneer Builders of Engineered Lubricating Equipment

42-100

LEWIS

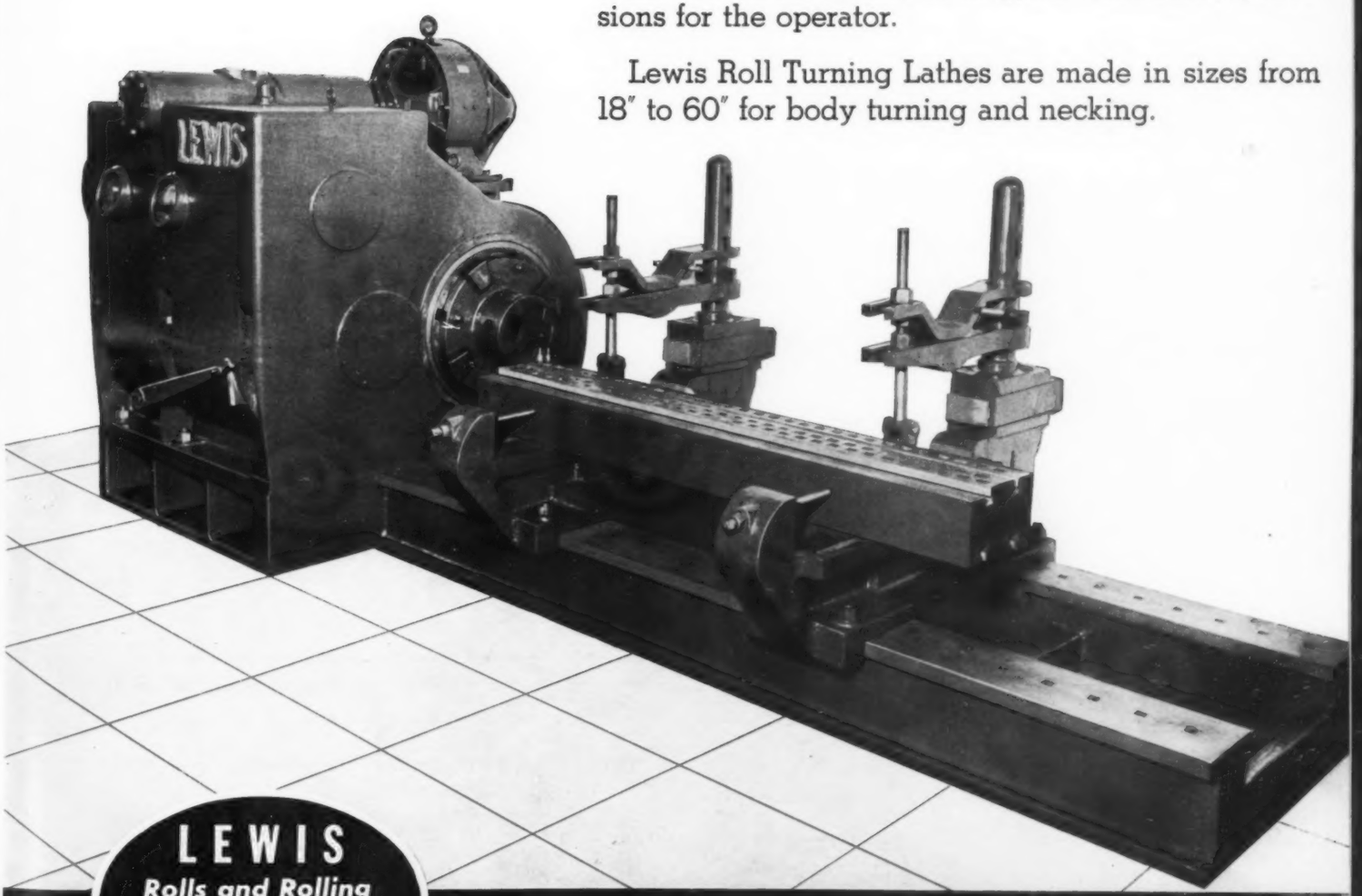
ROLL TURNING LATHES

NOT A SINGLE REPAIR PARTS ORDER IN 10 YEARS

The best proof of the sturdy and simple construction of Lewis Roll Turning Lathes is the fact that service records show no sales of replacement parts for the last ten years. These lathes are roller and ball bearing equipped with combination gear reduction for noiseless operation.

Specifications include totally enclosed headstock—worm and worm wheel drive—pressure lubrication—extreme accessability of all parts—and safety provisions for the operator.

Lewis Roll Turning Lathes are made in sizes from 18″ to 60″ for body turning and necking.



LEWIS
Rolls and Rolling Mill Machinery step up tonnage

LEWIS FOUNDRY & MACHINE
DIVISION OF BLAW-KNOX CO.
PITTSBURGH, PA.

Save Rubber and Copper... assure lasting trouble-free power distribution with Okonite V. C. Cables

For power wiring, you can't afford to overlook these timely advantages of Okonite V. C. Cable

REQUIRES NO RUBBER – SAVES COPPER
Insulated with varnished cambric instead of rubber, Okonite V. C. cable not only saves this precious material, but copper, too, can be saved as the higher heat resistance of varnished cambric makes it possible to use a smaller conductor to carry the same load.

EASY INSTALLATIONS
Okonite V. C. cable is fast and simple to splice, requires no special tools or methods. It handles easily.

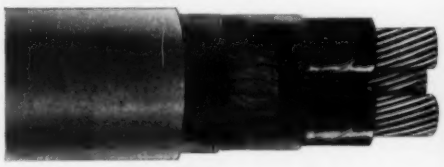
OUTSTANDING SERVICE RECORDS
Under all sorts of operating conditions and over long periods of time, Okonite V. C. cable has set records for trouble-free, lasting service.

FOR JOBS UP TO 28,000 VOLTS
Okonite V. C. cable is made in a complete range of sizes up to and including 28,000 volts. What's more, you can order it with various types of protective coverings to meet particular requirements best.

For complete information on Okonite V. C. cable or for help with any insulated wire or cable problem, call on our experienced engineers. They are ready to assist anytime without obligation to submit designs and estimates.

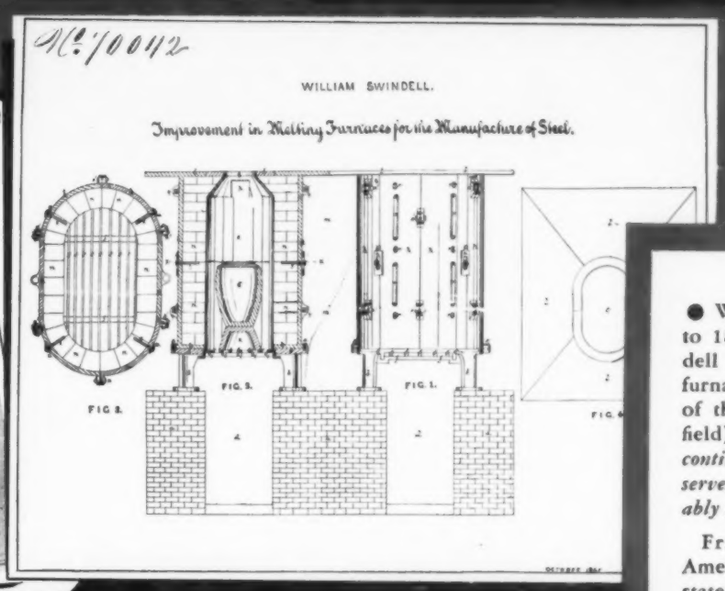
Meets all current IPCEA and Marine Specifications

THE OKONITE COMPANY
Passaic, New Jersey
Offices in Principal Cities



OKONITE
INSULATED WIRES AND CABLES

Over 90 YEARS OF KNOWING HOW



● We look back for a moment to 1850, when William Swindell designed his first steel-furnace (later to receive one of the earliest patents in the field), *only to emphasize the continuity of experience which serves our customers so invaluably today.*

From Steel's infancy in America to its present adult state, Swindell Furnaces have maintained their leadership . . . a fact doubly proved by unprecedented current performance in the nation's service!

SWINDELL ELECTRIC MELTING FURNACES

SWINDELL-DRESSLER *Corporation*

DESIGNERS AND BUILDERS OF MODERN INDUSTRIAL FURNACES

PITTSBURGH, PA.

VITAL INFORMATION ON A VITAL NEED

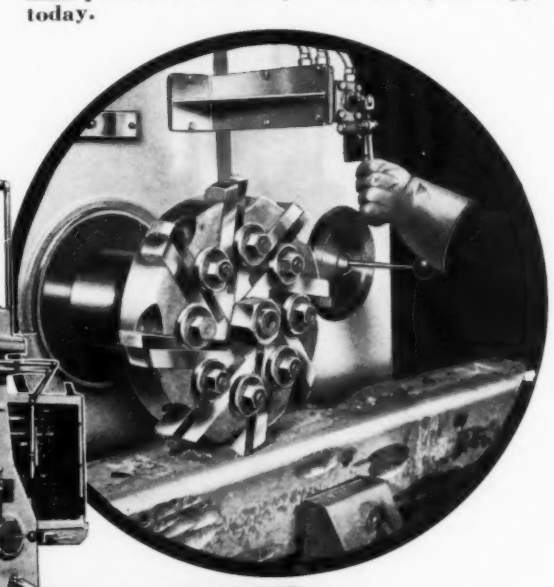
Super quality, quantity, and speed is the production battle cry! No phase of steel production — no department — can lag behind without hindering the Victory effort.

Presented in complete detail in this brochure is a billet-chipping machine that's geared to the times. Every operation, from the instant the operator presses the button that rolls a billet off the feed skids into the machine, to the final movement of the thoroughly cleaned billet over the discharge table, is speedily and efficiently accomplished by mechanical means. Only one operator is required; he has accurate and positive "finger-tip" control over every movement of the

BILLETEER

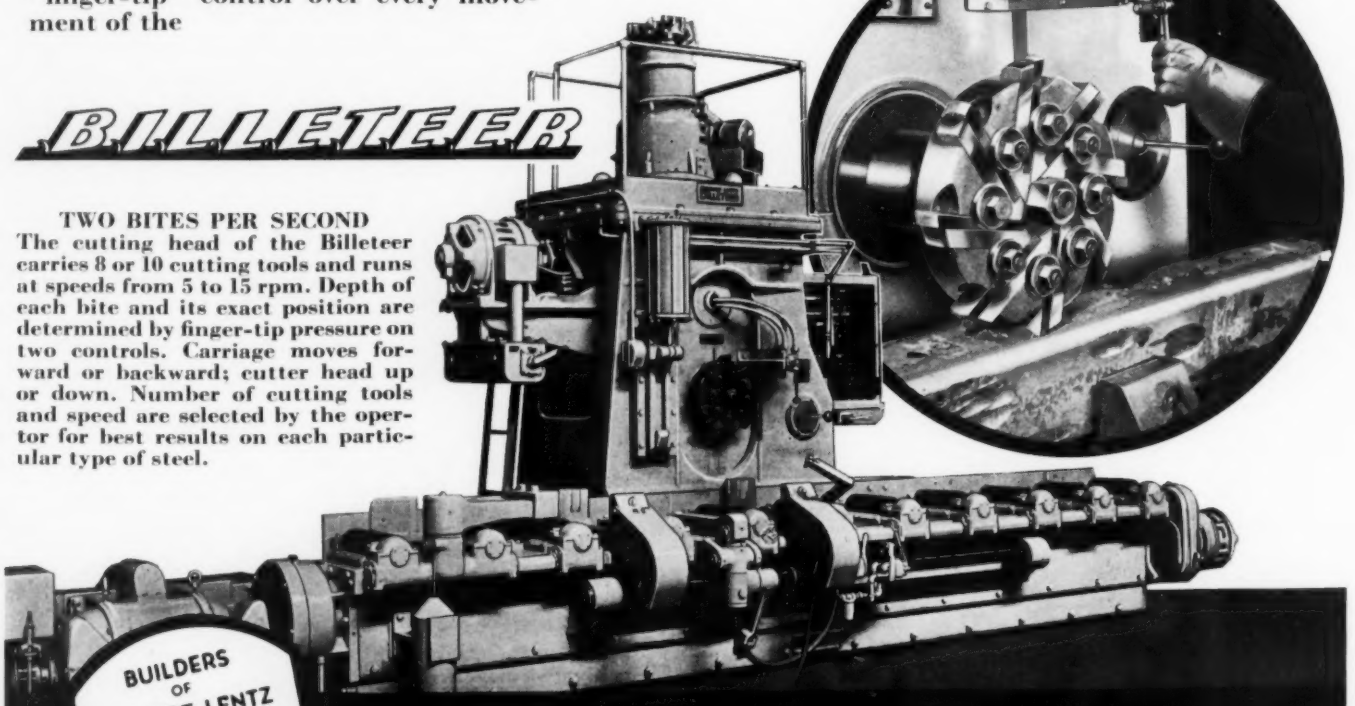
THIS BROCHURE

— shows how you can smash to insignificance the greatest record your Chipping Department ever produced by hand-chipping methods — and in less time with but a fraction of the usual man power! Don't delay — send for your copy today.



TWO BITES PER SECOND

The cutting head of the Billeteer carries 8 or 10 cutting tools and runs at speeds from 5 to 15 rpm. Depth of each bite and its exact position are determined by finger-tip pressure on two controls. Carriage moves forward or backward; cutter head up or down. Number of cutting tools and speed are selected by the operator for best results on each particular type of steel.



BUILDERS OF BONNOT-LENTZ BILLETEERS ALSO CRUSHING PULVERIZING AND MIXING EQUIPMENT

THE Bonnot COMPANY
STEEL EQUIPMENT DIVISION
CANTON, OHIO

The clutch of "the world's largest forging machine," built by The National Machinery Company, is equipped with two SKF Spherical Roller Bearings.

SKF

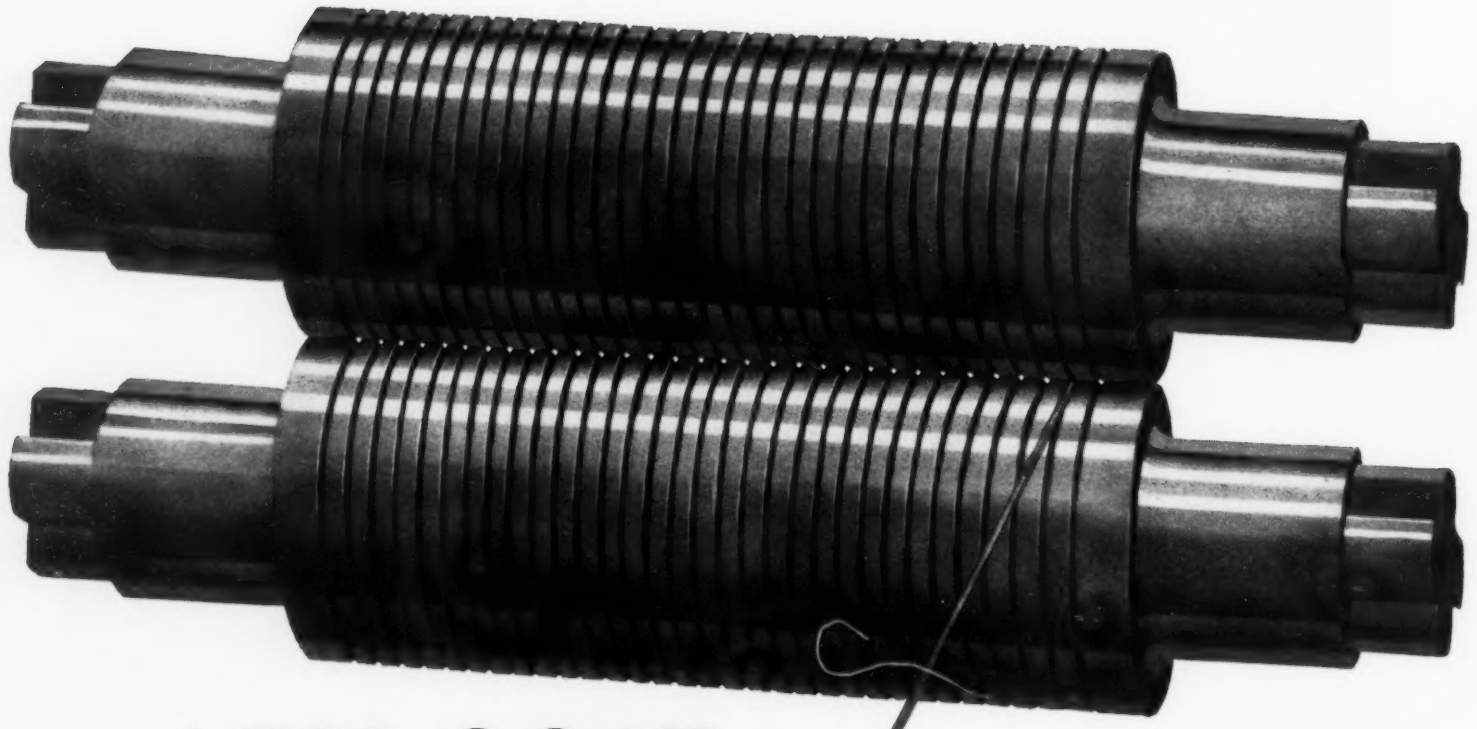
BALL AND ROLLER BEARINGS

Forging VICTORY *with* SKF *Bearings*

Not only on giant forging machines, but on the back-up rolls of steel mill stands, on cranes, on locomotives, on heavy duty equipment of all kinds used throughout Industry, SKF Spherical Roller Bearings are helping to forge Victory. You find them wherever War Production is dependent upon smoothly functioning parts . . . where bearings *must* stand up under punishing blows . . . where high bearing capacity *must* always be available despite shaft deflections, distortions or weave. Engineers know that NOW, more than ever before, they cannot afford to take chances with bearings.

5102

SKF INDUSTRIES, INC., FRONT ST. & ERIE AVE., PHILADELPHIA, PA.



LESS COST
PER TON OF
STEEL ROLLED

RODS

Pittsburgh Rolls are important factors in stepping up production and reducing costs.

PITTSBURGH ROLLS

PITTSBURGH ROLLS DIVISION of BLAW-KNOX CO.—"Steel's Partner" • PITTSBURGH, PA.

It's up to US...

First!

Strategically, the time might be right

THE enemies' over-extensions . . . the readiness of the "underground" and the guerrillas . . . the eagerness of our fighters — all the circumstances might be right . . . BUT —

The success of *this* year's offensive is up to *us*, all of us who read this magazine, who have the responsibility of *getting out the goods.*

Only when we have done our job can we hope to win.

Yale Pump Division Meets 1943 Schedules in 1942

Here at Yale & Towne's Pump Division, every man in our engineering department and in our shops knows that output considered good enough last December 6 is not good enough today.

We take pride in the fact that the war industries and our armed forces are receiving Yale Pumps at a rate we *had hoped* to reach in 1943! And standards of *quality* have been maintained throughout.

Today, the many cost-cutting, time-saving advantages of Yale Pumps are pledged to *victory*. Tomorrow, out of the trials and experiences of war, even more extensive peace-time uses for Yale Pumps can be foreseen.

TRADE **YALE** MARK

THE YALE & TOWNE MANUFACTURING COMPANY

Pump Division

211 HENRY STREET, STAMFORD, CONNECTICUT, U. S. A.

INDUSTRIAL EXECUTIVES!

THE SCRAP FROM YOUR PLANTS IS NEEDED AT ONCE TO KEEP WAR PRODUCTION MOVING!

YOU know that all our furnaces and mills must be kept working at top speed to win this war. Yet the steel industry, already producing record quantities, cannot attain its full, needed war-time capacity of 90,000,000 tons unless 6,000,000 additional tons of scrap steel is uncovered promptly.

This critical situation can be solved only by the patriotic cooperation of every American manufacturer.

In your plant, lying around in repair shops and storerooms, is the scrap America needs to give our boys the fighting tools they must have to win . . .

Broken castings, pipe, obsolete machinery, abandoned line shafting, pulleys, pumps, old boilers, storage tanks, beams, rails, fencing, track, chains, cable, rusty bolts, nuts, and rivets . . .

Round them up and get them moving to the front!

. . . Like the gas appliance manufacturer who searched his plant and found 90 tons of scrap metals . . . or the paper mill that "mined" 1,800 tons of steel from its plants . . . or the rubber company that asked its foremen to "stop holding things" and collected 1,608 tons of iron and steel from old molds and obsolete machinery in a single week!

What others have done, you can duplicate. Walk through your plant with "Scrap" in your mind—you'll be amazed at the harvest. But get it into the fight, *at once* . . . the war won't wait!

★ ★ ★

HERE'S WHAT TO DO... Appoint one man as Salvage Manager for your organization. Give him authority to *act*—to condemn old equipment, to move material, to collect scrap of all kinds. Have him separate all scrap by type. Then move it promptly through your regular scrap dealers. Don't wait — start rounding up scrap *now* — and keep your scrap moving until the war is won!

THROW YOUR SCRAP INTO THE FIGHT!

DONALD M. NELSON
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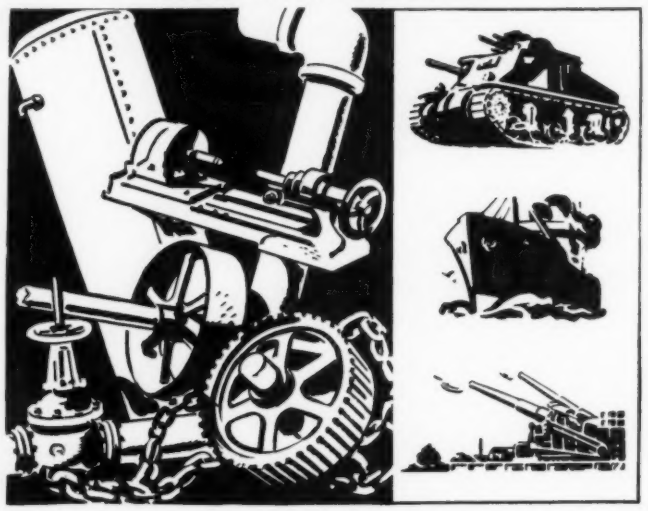

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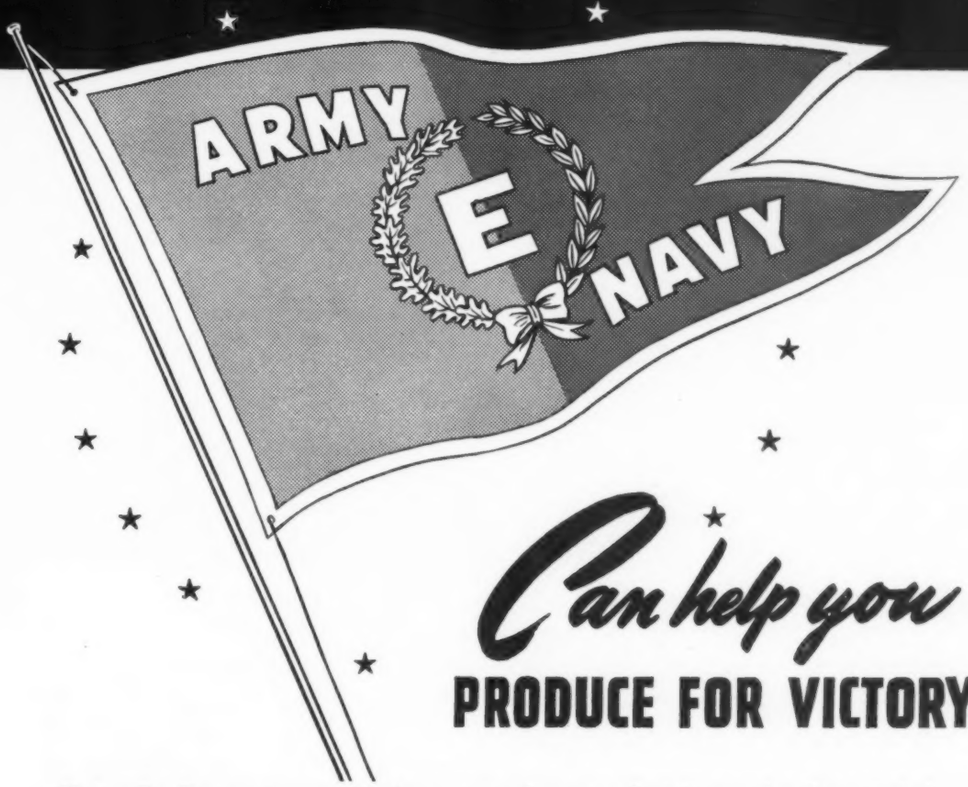

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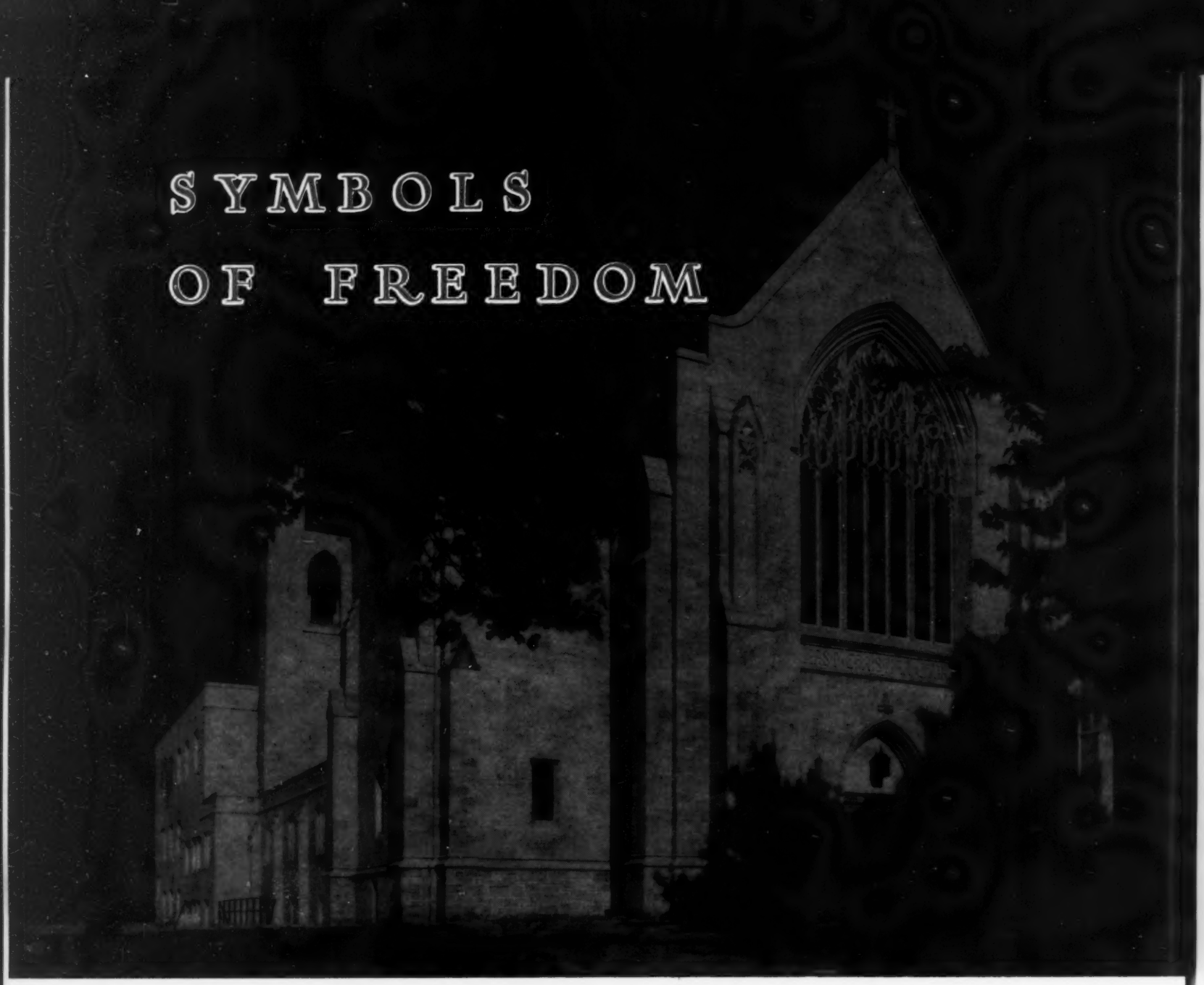

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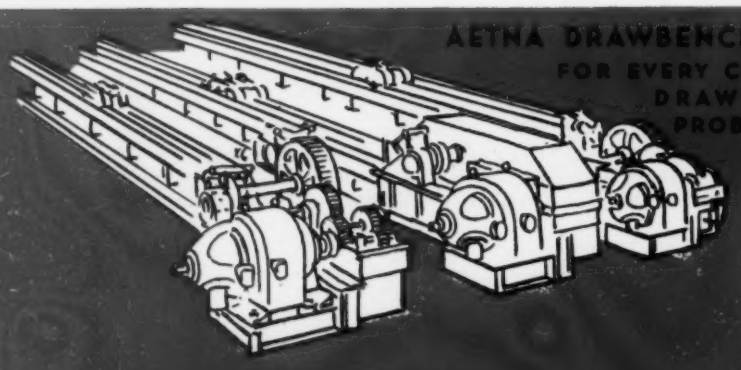

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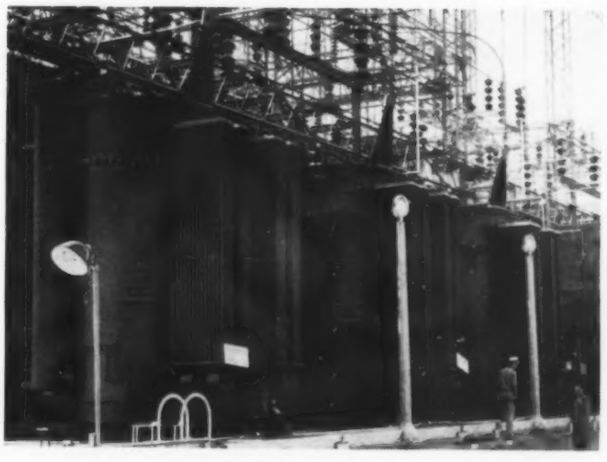

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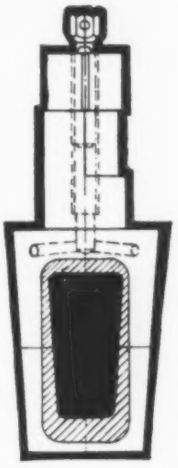

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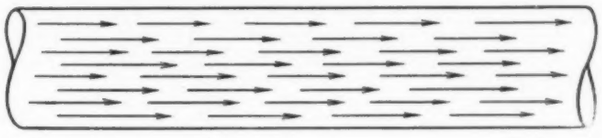

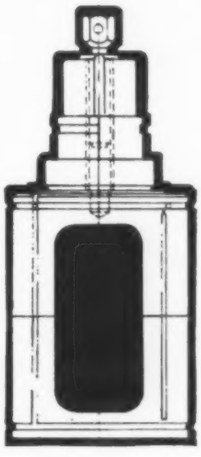

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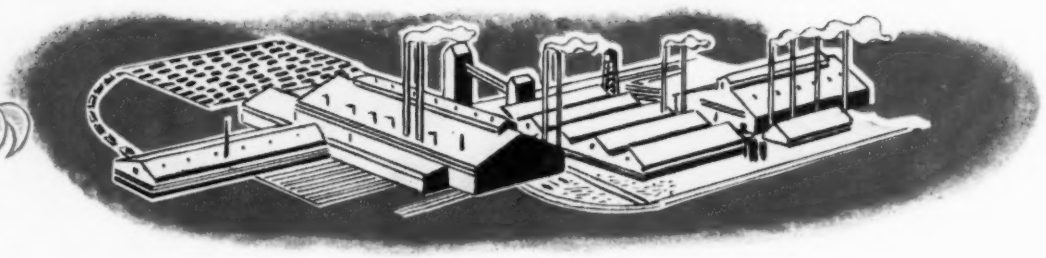

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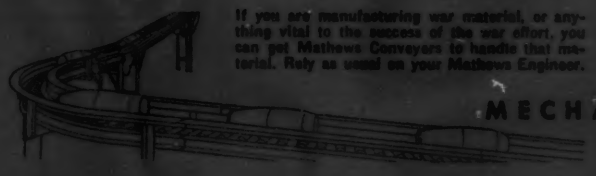

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APPLICATION and CONTROL of CAPACITORS on Multi-phase Loads

By W. A. Smiley

ELECTRICAL DEPARTMENT

Bethlehem Steel Company

STEELTON, PENNSYLVANIA

Presented before A. I. S. E. Philadelphia District Section, April 4th, 1942

. . . . plant power conditions improved by the use of novel transformer connections and capacitors . . . .

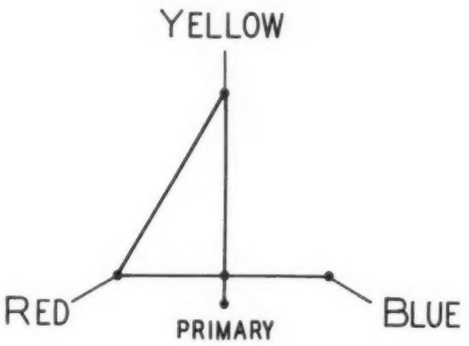
▲ IN the customary use of capacitors a common practice seems to be to estimate the requirement on the basis of correcting the power-factor of the load to a predetermined value, which popular opinion deems economical; purchase and install the capacitors; check the results for a time and then forget the matter until an operating condition or maintenance problem brings it forcibly to attention. We are not concerned with the customary and conventional methods of application and use, nor is it our intention to consider at length the economics of the use of capacitors since electrical literature is replete with the various aspects of the problem. We will consider briefly the shunt connected, single phase capacitor as applied to a multiphase system supplying severely unbalanced currents, and under conditions of use more common to the manufacturing plant than to the extraction industries.

Inasmuch as our discussion deals with an unsymmetrical, four phase system on which balanced loading cannot occur, it might be well for us to recall very briefly some of the defined and undefined limitations of our commonly used terminology and concepts. Let us first consider the term "power-factor." To many of us the term is synonymous with "cosine of the phase angle"; but since an unbalanced, unsymmetrical system possesses no phase angle, this concept of power-factor must be forgotten or rather limited to sine-wave, symmetrical, balanced, polyphase loads, and to single phase loads. This is in conformity with the A. I. E. E. definition which gives power-factor as the ratio between real power and apparent power. Unfortunately we have no instrument for the measurement of apparent power, although approximations have been made. We therefore find it more convenient both to measure and to think of watts and vars — that is, real power and reactive power, whether the circuit be balanced or unbalanced, symmetrical or unsymmetrical, single phase or polyphase; this is particularly true where capacitors enter into the problem. So let us discard for the time being at least, the concept of a capacitor as being a device for power-factor improvement. My personal conception of a capacitor is a device for reducing the current on an inductively loaded line. The accent is on the word reduce, and if we will think in terms of reducing current rather than in terms of increasing that abstract, dimensionless ratio, "power-factor," we will not only find more jobs for capacitors, but will more effectively use them.

Before entering into the description of a use to which we are putting them it will be necessary for me to describe in some detail a problem which was presented for solution. The company with which we are connected acquired, near the end of the late economic crisis, a plant devoted to making steel wire and cable. In the course of the rehabilitation program a survey was made under the direction of the superintendent of the electrical department, J. C. Reed, of the electrical layout and equipment of the plant, which were found to be in need of correction to bring them up to the required efficiency.

This plant derived its power from public service company lines at 11,000 volts, three phase, 60 cycles, with the load metered at the primary voltage. The energy was converted by two 750 kva transformers, Scott connected, to supply a nominal 440 volts, two phase plant system. Motor generator sets provided about 150 kw of direct current for crane operation. The distribution of the two phase current was by means of four-conductor underground cables buried directly in earth. At several points three wire motors were used on account of long runs of trolley wire, so that in effect the distribution was two phase, three wire, producing a potential of about 700 volts between one pair of lines. This excess potential was in part due to overvoltage operation to compensate for line drop. Due to the high inertia loads to be started by the various motors, overmotoring was necessary, with the result that the load power-factor was about 60 per cent lagging. At this low power-factor, cables were hot and a number of oil-switches were smoking. On account of the severe penalty imposed by the power company's schedule, about 600 kva of capacitors had been installed on the 440 volt bus, which gave about 80 per cent power-factor on the power company's lines, and also gave severe over-voltage during periods of light load. This over-voltage received some measure of tolerance due to the fact that the kilovar-hour meter ran backwards, being then without a ratchet, which enabled the average or billed

power-factor of 80 per cent to be attained. This overvoltage condition was probably a dominant factor in burning out, at different times, about 1200 kva of capacitor sections, which, however, the manufacturer made good. There were a number of other similar troubles which also required correction. The general condition is quite evident from the use of two phase power derived from a three phase service, and has or had numerous parallels in other plants which grew to considerable size during the two phase era, and when the public service companies changed over to three phase were not in a position to make the necessary expendi-



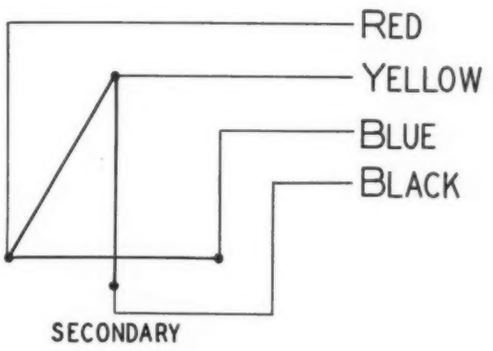
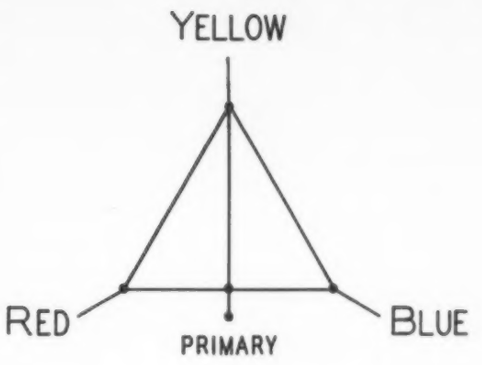


Figure 1 — Diagram showing open delta connection closed by main transformer joined to opposite apex of delta.

ture to change over at the same time. Later, additional two phase equipment was added a piece at a time until a change became a major operation and was no longer even considered.

In considering corrections to be made to the electrical set-up it was fairly obvious that a change to three phase was in order, since much additional equipment would most certainly be added to the plant, and it was difficult to justify paying a premium and awaiting long-term deliveries on equipment which was obsolete before it was ordered. Interchangeability of equipment between plants was to be desired, both from the standpoint of invested capital and also breakdown service. Maintenance of a fourth conductor and a fourth pole on control



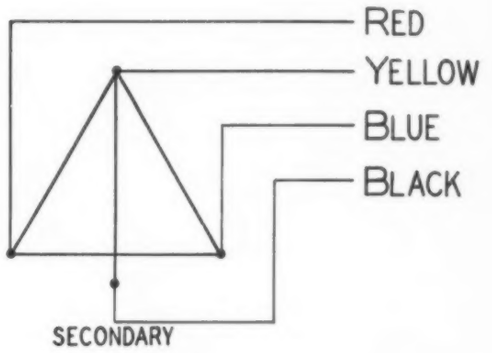
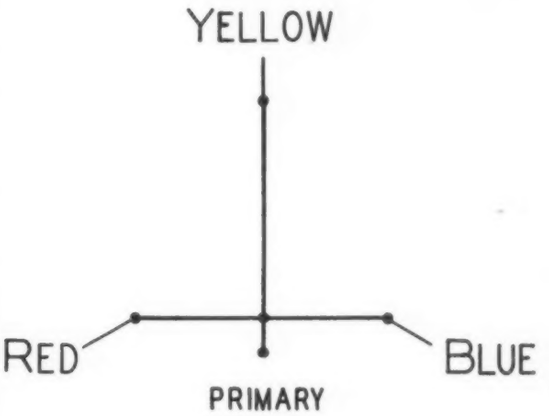
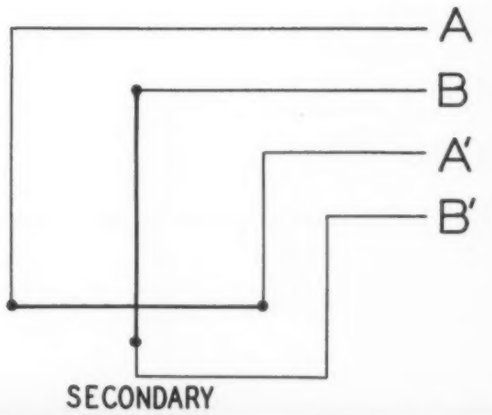


Figure 2 — Diagram showing the connections of Figure 1 for operation in the event of loss of one transformer.

Figure 3 — Diagram showing the emergency connection for two-phase operation in case half of transformers are out. This is the familiar Scott connection.

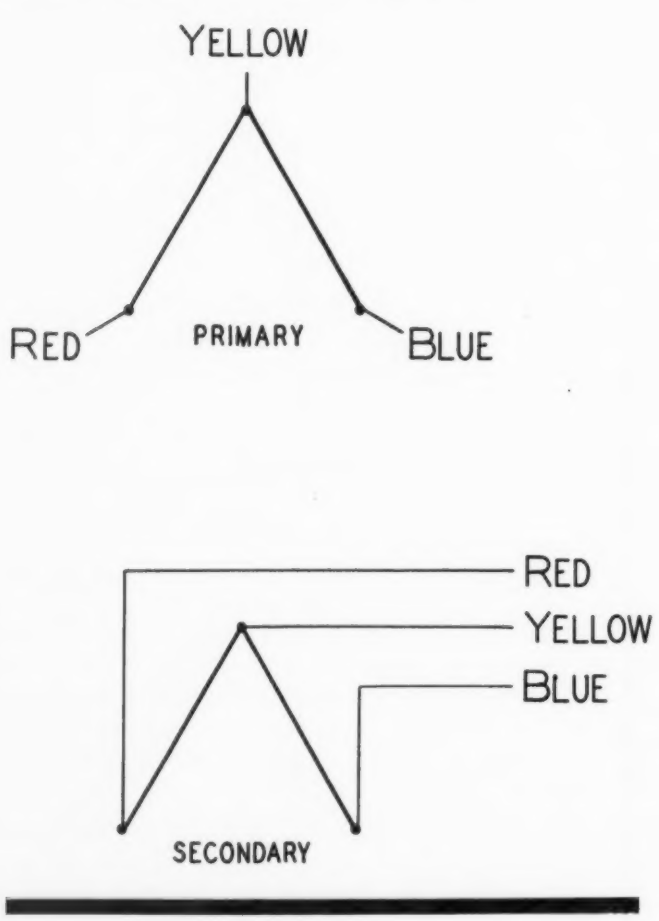




equipment were to be considered. The numerous other advantages of three phase operation are well known and the literature on making the transition is filled with various schemes. But in this case the various previously used schemes would not answer. The lines were already overloaded, and with underground lines the addition of large amounts of copper would be very expensive and besides the most of the addition would be practically wasted after the transition was completed. This last statement is probably not obvious, but the fact is that our four wire cables, rated on a thermal basis, will carry about 28½ per cent more three phase power than two phase, if we parallel the fourth conductor with one of the others for three phase operation. This ratio must, however, be distinguished from the 10 per cent increase indicated by assuming direct current phenomena. The effects of shields, sheaths, proximity, conductor size, bonding, etc., are susceptible of calculation where all factors are known, but test results are usually more direct, and reliable if applied only to the equipment tested.

It was further decided to correct the load to unity power-factor as measured on the public service company's lines, and to make the correction not on the 440 volt bus, but at the various load centers. The correction of load to unity power-factor may occasion some surprise as there is a more or less prevalent idea, which capacitor salesmen have assisted in propagating, that

Figure 4 — Diagram showing emergency connections for three-phase operation in case half of transformers are out. This is the conventional open delta.



it is not sound economy to correct to better than 85 per cent power-factor. With this idea we take issue on the basis that there can be no pre-conceived power-factor which represents an economic limit for a generalized case. Electric power systems, together with electrical loads and power supply schedules, are infinite in combination; each is a particular case and each presents its own problems and possibilities, wherein the generalized rule disregards factors which are often vital and determining. The factors most commonly overlooked are: transformer regulation; I^2R losses in lines and equipment; amortization of excess capacity of lines and equipment; reactive power increase of transformers due to load; effects of various conditions of loading; etc. Let us examine a few of these briefly. The inconvenience, if not to say evil, of transformer regulation is familiar to all of us. What may not be so familiar is that, as the power-factor swings down on the lagging side, this regulation approaches as its limit the per cent impedance volts of the transformer. Depending on the size and voltage rating of the transformer, this limit may be reached at power-factors which are not so low as to be considered serious. Furthermore, the trend in transformer design seems to be toward higher and higher impedances as a means of limiting short-circuit currents. An illustration of the effect of a leading power-factor load on a transformer of 15 per cent impedance was recently brought forcibly to my attention. Under the existing load the regulation of the transformer and its line was about 13 per cent until an additional load of about 20 per cent of the rating of the transformer was thrown on. This additional load was operated at a highly leading power-factor with the result that the regulation decreased to about 4 per cent and we have seen graphic voltage charts showing negligible regulation under load, for periods of more than 24 hours, when the overall power-factor was well on the leading side.

Another fact that may seem surprising is that the reactive energy taken from the supply lines by the transformer, as measured on a kilovar meter, increases as the square of the amperes load on the transformer if the current is lagging. That is to say, the kilovar meter will register a constant amount due to the magnetizing current plus an additional amount which varies as the square of the kva load on the transformer. To illustrate, if a given kilowatt load has unity power-factor we shall say the load has 100 per cent current; if the power-factor were 80 per cent, the current would be 125 per cent and the reactive meter would register a reactive energy affected by the factor 156 per cent. Even 90 per cent power-factor shows the reactive energy affected by the factor 123 per cent. If the power-factor of the load is leading this reactive component not only can be cancelled but even be made negative. This latter fact can be of some importance. There is a case within our knowledge where power is purchased and metered on the secondary side of the transformers, with both demand and energy, real and reactive, corrected for transformer losses. The load is variable with the light load highly lagging and the normal load well on the leading side. The public service company deducts certain amounts from the kilovar hours each month in recognition of the fact that the reactive losses of the transformer become negative under leading power-factor

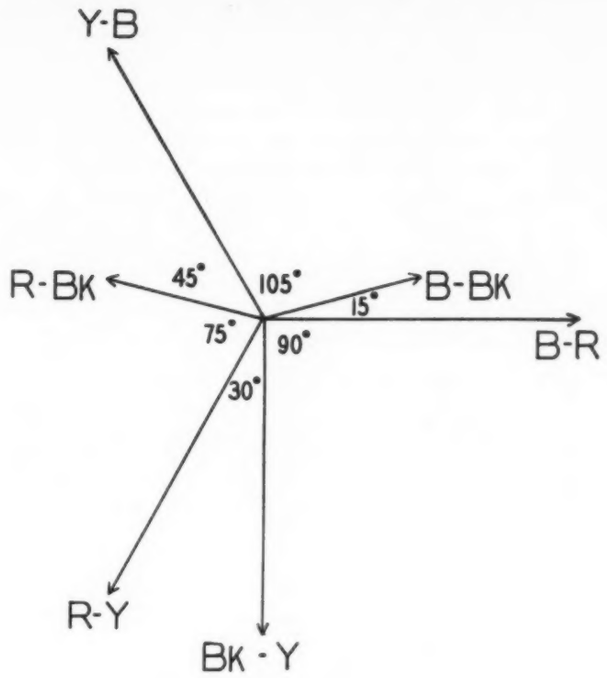


Figure 5 — Vector diagram of voltages under the scheme of connections shown in Figure 1.

load. Therefore we feel that the reactive component of transformer loss deserves careful attention in determining the extent to which power-factor correction can be made economically. It is not contended, however, that capacitors should not be used to establish a leading over all power-factor.

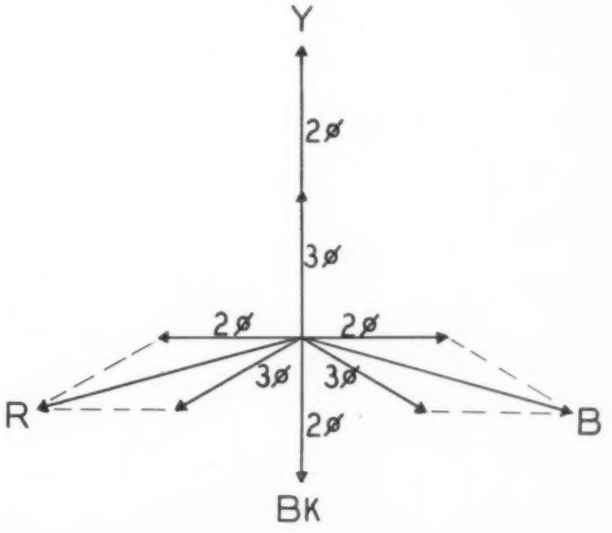
One of the places where capacitors show their greatest savings is in preventing copper loss. In fact, they have no other function. Various plants make different allowances for resistance drop; it may be 3 per cent, it may be 5 per cent, or it may be 10 per cent; but whatever the percentage is, that is the measure by which the cost of power is increased. As in the case of resistance drop, so it is with capacitors; the method of figuring our loss is very simple. The remediable loss at any power-factor, expressed in per cent, is the square of the reactive-factor. If the power-factor is 80 per cent, the reactive-factor is 60 per cent, and our preventable loss is 36 per cent; at 90 per cent power-factor we can save 19 per cent of our losses; at 95 per cent the excess loss is still 9¾ per cent. Furthermore, we need no book of tables for our calculations since by subtracting the square of the power-factor from one we have at once the per cent saving in losses which can be made by removing the "wattless" energy from the lines.

Now to consider our reasons for correcting our lines to unity power-factor. With a power-factor of 60 per cent we see that correction to unity will save 64 per cent of the copper loss and not only cool off the hot cables and smoking oil switches but give us reserve for additional load, on all lines, with the same heating and loss, since we get capacity to carry 167 per cent of the present load. Furthermore, when the change-over to three phase is complete we will get 167 per cent times 128½ per cent or about 214 per cent of our present two phase capacity, which, after some redistribution of load among the cables, will leave considerable reserve for additional load.

In carrying out our basic ideas there was the usual array of obstacles to be overcome. The plant had been placed in operation on a scale which was rapidly increasing. Over 400 motors, totaling about 4000 hp, were involved. It was out of the question to shut down even a section of the plant to rewind motors; they would have to be rewound only when taken out for repairs. Additional transformer capacity was required to add to the 1500 kva then in service to care for new motors to be added. In any scheme for the transition the scrapping of equipment at its conclusion was to be avoided. Also, some protection against shut down in event of transformer loss had to be included in the plan.

It was decided to purchase two new transformers to be duplicates of those in use so that complete interchangeability would be had in event of loss. The bank would then be connected four phase until the two phase load had become zero when one would be removed and serve as a spare. In the event of loss of one transformer we could still operate both two and three phase. In the event of loss of two transformers we could still operate either two phase or three phase, but not both; Figure 1 shows the scheme of connection. This is made up of an open-delta connection closed by the main transformer of the "Scott," with the teaser transformer joined to the opposite apex of the delta. Figure 2 shows the connection for operation in event of loss of one transformer. This connection uses the main transformer of "Scott" as one leg of an open delta and imposes certain additional complex load limitations as the ratio of two phase to three phase load varies. Figures 3 and 4 represent the emergency connections for two phase and for

Figure 6 — Vector relationships of the currents at identical power factors with equal currents on each system.

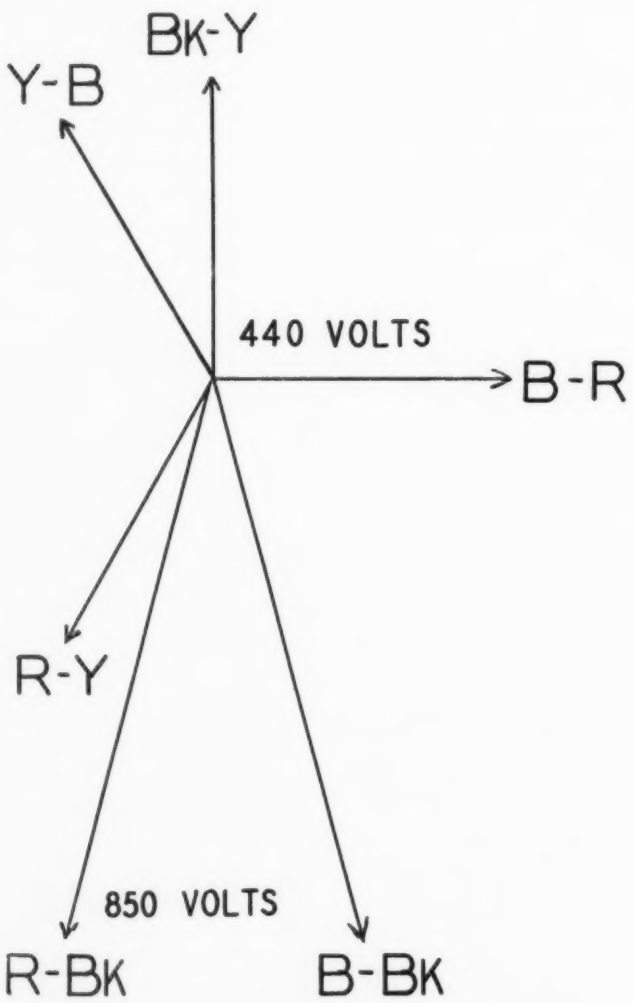


three phase operation in case half of the transformers were lost. These are the familiar "Scott" and open-delta connections.

The connections of Figures 1 and 2 are original, and so far as we know are new, and were adopted only after very considerable investigation of their load carrying ability as well as possible troubles or limitations. Up to this time the load has built up on them to about 80 per cent capacity, with a load factor in excess of 90 per cent, without any sign of distress or trouble developing. The production of harmonic voltages was a matter of some concern in connection with capacitor life, particularly so since the transformers are over-excited. Whether we may attribute any part of this satisfactory operation to the very consistent maintenance of unity power-factor load, is beyond our knowledge.

By referring again to Figure 1, it will be noted that the various lines are indicated "red," "yellow," "blue" and "black." The various lines, busses, switches, etc., were marked in these colors to permit prompt identification of any line. Since the plant was located about 100 miles from our office, positive designation of a given conductor was desirable when instructions were to be communicated. The American convention of naming the lines A, B, C, or 1, 2, 3, is hardly suitable for field use, whereas with color the identification persists so long as any bit of paint remains. The three phase sequence, red-yellow-blue, is the same as in the British system. For the two phase the sequence is blue to red, and black to yellow for the 90 degree separation.

Figure 7 — Vector diagram of voltages if connections were changed so as to reverse the polarity of the teaser transformer.



In Figure 5 is shown a vector diagram of voltages. In this diagram are shown also two spurious phase voltages red-black and blue-black, which are of no particular interest except that they are unavoidable on any four phase system. In this case the magnitude of these voltages is 51¾ per cent of a true phase voltage.

By referring again to Figure 1 we see that three of the phases terminate on the yellow wire. Two phases terminate on each of the red and blue wires, and one phase only terminates on the black wire. From this, the statement above that balanced loading of the lines was impossible, should at once be clarified. For the three phase load the yellow wire carries the vector difference of the yellow-blue and red-yellow currents, to which is added vectorally the yellow-black current of the two phase system. At identical power-factors of the two phase and three phase systems, the two phase and the three phase currents are in phase and the total yellow current is the arithmetical sum of them. In the cases of the red and blue lines the case is slightly different. For the red wire the three phase current is made up of the vector difference of the red-yellow and the blue-red currents, to which must be added the red-blue two phase current. At identical power-factors the two phase and the three phase currents have a displacement angle of 30 degrees. Their vector sum is therefore less than their arithmetical sum. For the blue wire the condition is similar to that of the red wire. In Figure 6 is shown the vector relationships of the currents at identical power-factors with equal currents on each system. At this point it might be suggested that since the yellow two phase and three phase currents are in phase, we should reverse the polarity of the teaser transformer so that the yellow-black current flows in the opposite direction, upon which the yellow currents of the different systems would cancel each other and instead of a seeming overload we would have no current at all in this wire under the condition shown, and would have a minimum of current under other possible conditions. This is a tempting suggestion, but like all such suggestions it prompts a bit of caution. If we take a hint from the law of conservation of energy, we must conclude that when a current is reduced or eliminated and energy remains constant, some other factor has been changed. Energy is voltage times current, so we may expect a change in the emf set-up. In Figure 7 is shown what would happen by such a change. The spurious phase voltages are no longer 51¾ per cent, but are now 193 per cent of the phase voltage. In this case this emf would be 850 to 890 volts which is excessive for 600 volt wire, and 440 volt equipment, as well as hazardous for the men who work with it.

The loading of the four lines as shown in Figure 6 holds true only for a condition wherein the power-factors of the three phase and two phase loads are identical. For the case when the three phase load and

the two phase load have dissimilar power-factors, with the three phase power-factor on the leading side — that is, both power-factors may be either leading or lagging, or one leading and the other lagging, but with the three phase more leading or toward the leading side — we have the condition shown in Figure 8. This shows the condition for equal line currents for each system load, but with the three phase at unity power-factor and the two phase at 60 per cent power-factor lagging. In this case the red and the yellow currents each have been reduced, but the blue has increased and approximates the arithmetical sum of the currents composing it. This arithmetical sum is attained if the phase angles of these systems differ by 30 degrees. This is quite apparent in Figure 6.

In the case when the relative power-factors are reversed from that above referred to Figure 8, we have the condition shown by Figure 9. In this case the red current approximates the arithmetical sum of its components. This figure shows the two phase load at unity power-factor and the three phase load at 60 per cent power-factor lagging. It should be noted that the power factor difference in each of Figures 8 and 9 is 60 per cent, corresponding in these cases to an angle of about 43 degrees, so that certain of the vectors for the currents in the different systems have crossed over and are now diverging. This condition will be found very interesting if studied in connection with load variation. Study of Figure 9 also reveals an important point. The loads in this figure are shown as equal with the three phase power-factor not corrected. Or it can be read to show the two phase over corrected and the three phase under corrected. It will be noted that for the condition stated the three phase current is now about 167 per cent of the two phase current. About 15 per cent of this excess is due to the higher current per kva required on three phase, and the balance is due to lack of correction. At about the time in the transition from two phase to three phase, when the loads on the two systems are equal, care must be taken to properly apportion the capacitors among the phases.

It may be considered axiomatic that the best loading on any electrical system is bad if the sums of the squares of the currents in the several conductors is a minimum. In a symmetrical system this would mean that the currents are equal and without a reactive component. In an unsymmetrical system, on which are imposed single phase, two phase and three phase loads, the currents cannot be made equal in practice, but the sum of their squares can be made a minimum. Nor can the currents be made without reactive component, but the sums of the squares of the reactive components can be close to zero with the individual components held to negligible values. To this end the single phase capacitor is ideally suited.

Given four conductors, we have six choices of a pair of lines to which a capacitor can be connected. When this is done we have remaining five choices; then four, etc. This extreme flexibility is available but need never be used unless some extremely unforeseeable condition were to arise. The spurious phases are not loaded and hence a correction involving them is available but of little economic significance. We can thus limit ourselves to four choices of capacitor connections. In Figure 10

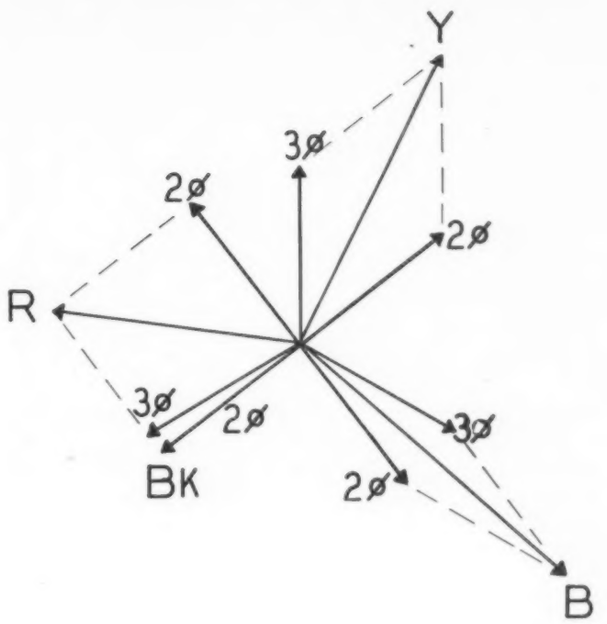


Figure 8 — Current relationships for equal line currents for each system load, but with 3-phase at unity power, 2-phase 60 per cent lagging.

we have a vector diagram of the voltages and of the currents produced in each wire by application of capacitance across each voltage. It will be noticed that we have but one choice of current phase position for the black wire; for the red wire we have two; for the blue wire two; but for the yellow wire we have three. From this it can be seen readily, without going into a lengthy exposition, that corrective currents in chosen but not necessarily equal amounts may be produced in selected wires to accomplish almost any desired correction of current magnitude or of the phase relationship.

In applying capacitors in this way, care is necessary in choosing proper equipment. It is apparent that a bus per line is required, to extend the full depth of the rack. Fuses, if used, should be provided at each terminal of each condenser unit. The mounting and wiring should be such that the units can be transferred from rack to rack as required, and connected to the proper lines, with a minimum of shut-down time on the equipment. Shifting of units is very infrequent but should not be a major operation lest it be neglected when the time comes to do it.

It may be contended that where the only loads on this system are two phase and three phase, only two phase and three phase applications of capacitors would be required. This is correct if the only purpose in mind is to correct the individual loadings for power-factor and consideration is not given to losses which are concealed on the power bill. In the previous discussion we have dealt exclusively with these concealed losses without any mention of the economics of the power company's penalty or bonus for averaged power-factor. When capacitors are considered, the first question often asked is "What will be the new power-factor and what

will it save us?" We do not hold with this method of approach to the problem, since in many rate schedules the power-factor affects only the demand for which you pay and there is concealed in the item of kilowatt-hours very real possible savings. Many methods, not involving heavy investment, are available for more effective reduction of demand charges. Superimposed peak loads often do more to build up demand than power-factor correction can possibly reduce. The preferred method might well be repeated: if we reduce the sum of the squares of our line currents to an economic minimum, our total overall cost of operation will be a minimum. The technique and underlying electrical relationships of this method are deserving of more careful study, but in a discussion of our subject we have neither the time nor the space to devote to the exposition which this one thought really deserves. However, let us examine one single aspect. From the standpoint of the management (who must render an accounting of their stewardship to the stockholders), operating conditions, technical arrangements and the like are of minor interest. The vital aspect of capacitor use is the return on the investment which can be evaluated in terms easily understood. The plant under consideration could have been operated by either of two additions to the equipment: $6000.00 could have been spent for additional copper; or for capacitors and control apparatus. Of these alternatives the copper need is much more in evidence. When a wire is hot you can always take the boss out into the shop where he can determine to his own satisfaction that he will have to buy more wire or shut down the plant. In this case what was not so physically evident was that the stated amount of copper would have had negligible affect on the power bill. Underground cables are expensive both to purchase and to install. Additional feeders also involve terminal and distribution facilities. It is therefore obvious that we need not evaluate this method of relief. In this case of capacitors let us consider only those two items from which the savings are greatest and most easily calculated: copper loss and power-factor improvement.

The bases of our calculations are: demand 2000 kw, 1,325,000 kwhr per month, load factor 92 per cent, power-factor unity versus power-factor of load 60 per cent corrected on the bus to a monthly average of 70 per cent. Under these conditions, which are representative of January operations, and do not show later higher loads and greater opportunity for savings, the effect of power-factor on the yearly bill for power amounts to a saving of $5,100.00. A return on the investment of 85 per cent.

For the copper loss the bases of our calculations are the same, except we shall assume all three phase loading which represents the final changed-over condition. We have shown that we can carry 214 per cent load with the same losses as before the change. This is the same as saying our losses are 46¾ per cent of our former losses, or that we are saving 53¼ per cent of our previous copper loss. Since the reactive drop in our cables is quite negligible, the entire drop can be assumed as resistance drop and as the measure of our loss. The previous drop exceeded the present drop by over 10 per cent. Using 10 per cent we see that our cable loss would have been 10 per cent of 2000 kw or 200 kw. This is affected by the load factor 92 per cent, which gives us an average loss in our cables of 194 kw. In a year this amounts to 1,700,000 kwhr lost. Of this we save 53¼ per cent, or 905,250 kwhr per year. Using a residual power rate of 5 mills per kwhr, this saving amounts to $4,525.00. A further return on our investment of 75 per cent. This brings the total saving from these two factors alone to $9,625.00 a year, which is at the rate of 160 per cent return on the capital. There are few investments yielding such return, and it is to be noted that this return is for correction to unity power-factor which many consider unprofitable.

It is worthy of more than passing notice to observe that in this practical example, the savings due to copper loss are almost identical to the rebate made by the power company for the losses saved them. We cannot expect, however, that the power company will rebate an amount fully equal to their savings. They are not in business to make power, but rather to make a profit. From these considerations we may draw a conclusion,

Figure 9 — Current relationships with line currents remaining equal, but with 3-phase at 60 per cent lagging power factor, 2-phase at unity.

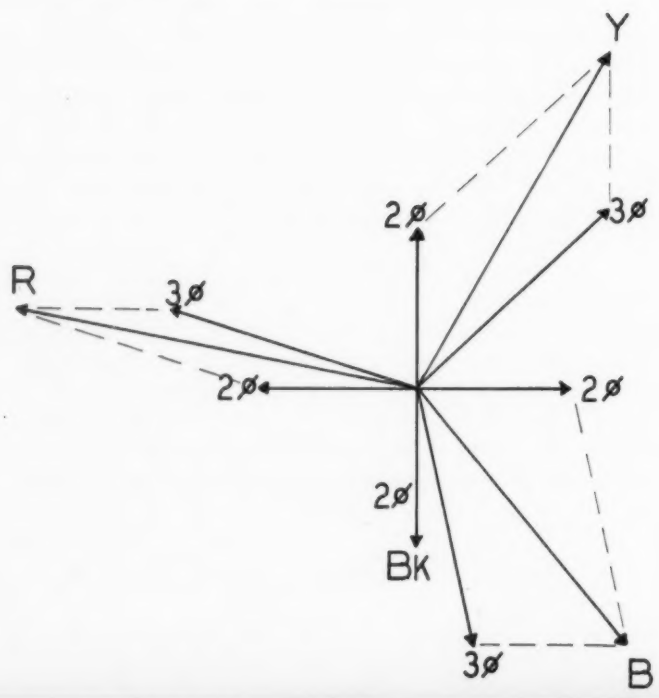
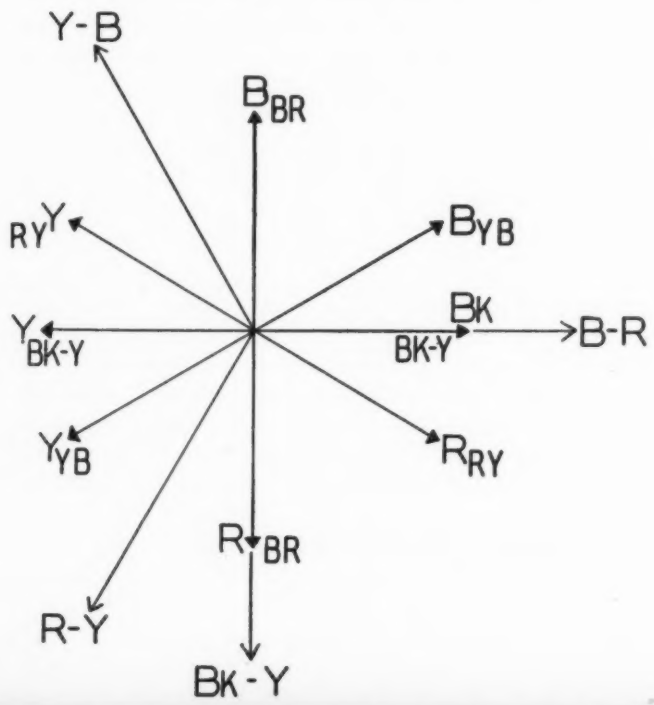


Figure 10 — Vector diagram of voltages and currents produced in each wire by application of capacitance across each voltage.



if not a general rule. The savings which may be realized will, in general, exceed twice the amount representing the power company's rebate for the correction. This can, of course, hold true only for those rate schedules which have an economic rather than an arbitrary basis.

The foregoing has dealt with the application of capacitors to a particular and somewhat complex system not often found. The underlying principles, however, apply to any system. In making any application, be the engineering ever so good, the installation will yet fail of attaining its full possibilities if the operation, that is the control, is not as carefully considered. Loads will vary. Departments may not be in operation. The requirement for capacitors may vary from hour to hour, or even continuously. If the maximum over-all economy is to be had we must add and remove capacitors from the circuit in accordance with the requirements of the load.

Unfortunately there is no general solution to a problem of this kind, and each installation must be tailored to fit the particular plant layout, method of operation, type of load, etc. There are fortunately certain principles which may serve as a guide; and unfortunately there are certain limitations in the amount of abuse capacitors can take. One limitation of a capacitor is that it cannot be switched on and off the line every few seconds, nor is it desirable to switch large blocks very frequently on long lines on account of the charging currents under out-of-phase relationships.

The basic factor on which control is determined requires some consideration. Power-factor, as well as voltage, has been used as the determining factor, but when these are used we are initiating action by the effect we hope to get from the action. If we switch in a capacitor at 80 per cent power-factor and switch out at 90 per cent, and our capacitors are all of the same size, varying numbers of units must be switched according to the size of the total load. At lighter loads a single unit may increase the power-factor beyond 90 per cent, with the result that it will be switched in and out as rapidly as the control can operate. The same is true of voltage control, with the added disadvantage that the correction secured is a function of the voltage fluctuation of the supply lines. The natural control factor is the measure of the correction needed and supplied. Correction is measured in reactive kva, or kilovars, as is also the need for the correction, and when the reactive kva is zero our preventable losses are also zero. There are certain advantages to be found in polyphase kilovar relays which do not exist in other control mechanisms; not only do they perform correctly when currents are unbalanced, but they have certain mechanical superiorities.

In Figure 11 is shown the main control panel for the described installation. On this panel are mounted the kilovar relay with its test switch, a timing and control relay assembly, and eight patch cords and receptacles for sequence selection. In this set-up the kilovar relay is connected in the incoming line to the substation so that the reactive power measured includes the transformer bank. The kilovar relay is adjusted to switch in a capacitor at about zero and switch out at a point about 25 per cent above the rating of a capacitor unit. In this way a slight excess of leading reactive kva is on the line, not only to reduce switching but to care for

Figure 11 — Main control panel for capacitor installation, including kilovar relay with test switch, a tinning and control relay assembly, and eight patch cords and receptacles for sequence selection.

starting current of motors and slight load variations. This corresponds under the maximum condition to a power-factor of about 99.8 per cent leading. This is desirable since the timing relay imposes a delay of 25 seconds *before* a capacitor is switched. During this delay period the need for the change must be continuous and without interruption. If interruption of the need occurs, the time delay relay resets and a new period is timed. This prevents capacitor switching on demands of momentary duration, such as motors starting.

The timing relay operates a selector switch which rotates to cut-in or to cut-out additional pilot relays, which in turn operate to close the magnetic contactors at the capacitors. By the interposition of these pilot relays, low voltage can be used on all controls and the panel is isolated from power circuits, as well as from any faults which might originate on them. The pilot relays feed power to a series of receptacles, from which patch cords complete the circuit to the capacitor contactors. These patch cords enable the selection of the sequence in which the capacitors are switched. If various departments start their operating schedules at different times, the set-up can be adjusted to fit the sequence. In this illustration it will be seen that the patch cords are inserted to fit an operating sequence.

This equipment was installed in 1939, and since then the load has grown considerably, but 99 per cent power-factor appears regularly on the power bill, and in one month we reached 99.97 per cent, which was credited as unity.

To epitomize the economics of the installation, it is sufficient to say that the savings have repaid the cost several times, and we are now saving the equivalent of one month's free power each year.

ELECTROLYTIC PROTECTION of Water Systems

By Paul S. Armstrong

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Fraser-Brace Engineering Co.

MEADVILLE, PENNA.

Presented before A. I. S. E.
Philadelphia District Section
April 4th, 1942

. . . . electrolytic protection of water systems is positive and practical . . . . results depend on type of water, dissolved salts, temperature, voltage and amperage . . . .

▲ IN the summer of 1940 the City of Easton, Pa., found it needed to protect its two water tanks from corrosion. One tank had not been painted for over twenty years; the other was painted within two years and it was found that the paint job was not satisfactory. About this time the city became interested in the cathodic protection of water tanks and, after investigation and study of the two present commercial systems on the market, was convinced that cathodic protection of water tanks is satisfactory and practical for the prevention of corrosion and that it is superior to any paint or bitumastic protection.

This decision to install cathodic protection brought up the question of the effect of this type of protection on the chemical constituents of the water in one of our two water systems. This water in question is one with a low alkalinity and pH and with a very slight change in either one it would throw it on the corrision side of the calcium carbonate saturation curve. Red water had been a headache for a number of years and it was deemed advisable not to install any cathodic protection until some definite information could be obtained as to the effect of cathodic treatment on the chemical constituents of the water.

Through the kindness of the Electro-Rust Proofing Company of Dayton, Ohio, and the Rusta Restor Company of Freemont, Ohio, equipment was secured with which to carry on the experiments.

At first thought this appeared to be a short and simple experiment, merely one of passing a current through a tank of water, making chemical analyses before and after, and noting the changes. It became evident in a short time that the solution to this problem could not be answered in a few months of research because too many variables are present in water, and any results obtained would apply only to the water in question; and to try to predict what effect cathodic protection might have on different waters would be unwise with this amount of research data.

The tank which it was sought to protect from the action of a sensitive water, is a circular one-half million gallon, iron riveted tank, 120 feet in height, 25 feet in diameter. It floats on the system; the common fill and draw pipe is three feet from the bottom. A typical analysis of the tap water is found in Table I.

For the first experiment a used 40-gallon, hot water tank was used with a copper oxide rectifier and a stainless steel ½-inch diameter electrode; both of the latter equipment were furnished by the Electro Rust Proofing Company. A supply line and overflow were placed on this tank and the dimensions of the experimental tank approximated those on our stand pipe. A continuous discharge existed at all times and the tank was filled from four to six times per day, simulating the conditions of the stand pipe. This type of tank was used, figuring it would be a severe test for our experiments.

TABLE I—Results in Parts per Million

pH	M.O. alk.	CO_2 free	Total solids	Ash	Iron total	SiO_2
8.47	28	none	73.2	49.0	.106	7.1

Fe_2O_3 Al_2O_3	Al_2O_3	CaO	MgO	SO_3	K_2O-Na_2O
1.15	1.04	19.6	4.65	10.23	4.8

These experiments extended approximately for 5 months, using various amperages and voltages. The results are as in Table II:

It soon was evident that this was a test under conditions not experienced in actual practice, as the rust in this type of tank is made up of deposits not found in standpipes and, with the current used, the iron rust in the experimental tank was not removed as rapidly as was desired, but there was definite physical evidence that some of the iron rust was being removed. At this point it was a question whether the increase of total iron and color in the experimental tank was due to the current alone; therefore experiments were made in glass beakers, one containing iron nails and the other without. The results definitely showed that water standing in contact with iron or iron rust will drop in pH, methyl orange alkalinity, and increase in total iron and color, therefore the increase in total iron and color in Table II is not all due to the effect of the current. It is also recognized as a fact that water without contact with iron will drop in pH and methyl orange alkalinity.

A tank was therefore constructed from stove pipe iron in sections with the following dimensions: 12 in. in diameter, 67 in. high, overflow 64 in., and a 8½ in. surge line. A great many chemical analyses were made as in Table II and during the course of the test it was again very evident that the iron rust was not being removed fast enough for progress, although various voltages and amperages were used; therefore the tank was cleaned mechanically as well as possible and, after two days with the current on, the last traces of rust were removed, and the results, using a stainless steel electrode, are evaluated in Table III.

Several effects were noticed in this tank; the tank showed areas freed from rust in vertical strips down the side of the tank, and around the rivets. No sign of gas on the inside of the tank or stainless steel electrode was noticed until all iron rust was removed. It was desired to use this tank without any rust but the tank leaked after construction and before it was made water tight it had become rusted.

This brings us to the theoretical and practical reasons for the cathodic protection of iron tanks. In the commercial field various explanations are given, such as a protective film of hydrogen forming on the side of the tank. From a study of electrochemistry, and of the electro-motive series, the real reason is apparent. According to Faraday's laws the magnitude of the chemical effects produced in a circuit is proportional to the quantity of electricity that passes through the circuit, and the quantities of the different substances which separate at electrodes throughout the circuit are directly proportional to their equivalent weights. The first statement is true under all conditions, but the second only for the case that a single substance is liberated on any given electrode. If several substances are deposited together on the same electrode, there is, of course, less of each than if only one is deposited. The electrochemical constant, or the quantity of electricity necessary to deposit one equivalent weight of any substance is equal to 96,540 coulombs or the unit of quantity is the coulomb which is the quantity of electricity transferred by a current of one ampere in one second. In practical installations we have only the removal of iron oxide and no deposition of calcium salts for the first statement, and removal of iron rust and the deposition of calcium salts on the tank wall as the second statement; besides calcium salts this deposit may consist of other elements as well as calcium.

Reduction is a term applied to several different processes one of which is the loss of a positive electric charge by an ion, as when ferric iron, such as iron rust, changes to ferrous oxide. Of course the reduction resulting from the addition of hydrogen is dependent on the deposition of hydrogen on the cathode, which reacts while in the nascent state with the reducible substance with which it comes in contact. Molecular hydrogen has very little reducing power and consequently the reducing power of a cathode or the tank wall must be ascribed to the hydrogen liberated on it while in the nascent state. According to the mass action law, the reducing power of nascent hydrogen is proportional to its concentration. In this experiment no hydrogen gas was visible on the cathode or tank wall until all iron rust had been removed. The explanation is that the nascent hydrogen reduced the iron rust on the side of the tank to ferrous oxide or metallic iron and thus loosened its hold on the side of the tank, which was evidenced by the deposition of iron rust on the bottom of the tank. In a later experiment a carbon electrode was used and in both cases the results were the same. After the iron rust as removed from the side of the tank hydrogen gas was found on the side of the tank. The explanation is that the ionic hydrogen moves to the side of the tank, discharges its electrical charge, changes to nascent hydrogen in a gaseous form and immediately reduces the rust and loses its gaseous form; therefore no gas bubbles of hydrogen were visible until all of the iron rust was removed. At the same time when both stainless steel and carbon electrodes were used nascent oxygen gas collected on the anode which also oxidized the iron or carbon, whichever the case might be. In the case of the stainless steel electrode the nascent oxygen oxidized the iron to iron rust or iron oxide, in a molecular or ionic form, which was evidenced by the increase of iron in solution and by the increase in color. In the case of the carbon electrode the nascent oxygen oxidized the carbon electrode to carbon dioxide, which was evidenced by the collection of carbon dioxide gas on the anode. In the case of the stainless steel electrode an appreciable loss in weight from the end of the electrode was noticed with an increase of color and total iron in solution.

In the case of the carbon electrode a reduction in color was found; no visible loss of carbon was shown as the electrode was not weighed before the experiment, but there must have been a loss due to the oxidation effect of the nascent oxygen. It should also be noted that in practical installations it requires 50-70 per cent more power cost with a carbon electrode versus a stainless steel electrode.

When an electric current is applied to a tank of water, at first only a small diffusion current will flow, but when the decomposition voltage of the salt or salts is reached, electrolysis will begin. The point of electrolysis in the cathodic protection of water tanks begins at the point at which the water is electrolyzed, and ionic hydrogen deposits on the side of the tank. The decomposition point is the sum of the potential differences at the anode

TABLE II

All Results Expressed in Parts per Million

Date	Sample	pH	M.O. alk.	CO_2	Soap hardness	Color	Total iron	Current	Note
8- 7-40	S B T	7.9 6.1 6.5	32 17 13		55 46 47	18 95 40	0.95 4.05 1.55	E = 11.5 V I = 0.24 A	W.L. ½
8- 9-40	S B T	7.9 5.8 5.9	31 7 8		54 43 44	18 65 40	0.80 3.25 1.60	I = 0.24 A	W.L. ⅓
8-12-40	S B T	7.9 6.0 5.9	31 11 9		54 42 44	10 60 40	0.30 3.05 2.45	I = 0.24 A	W.L. 1/5
8-14-40	S B T	7.9 6.1 5.1	30 14 6		55 45 41	8 45 45	0.42 2.35 2.50	I = 0.24 A	W.L. ¾
8-16-40	S B T	7.8 6.4 4.9	30 17 2		55 44 43	8 45 40	0.35 2.50 2.40	I = 0.24 A	W.L. ½
8-19-40	S B T	7.9 5.3 4.7	30 6 0		57 43 42	7 50 40	0.18 2.20 2.95	I = 0.24 A	W.L. ½
8-21-40	S B T	7.9 6.1 4.7	29 14 0		58 44 43	5 55 49	0.11 3.20 2.80	I = 0.24 A	W.L. ¼
8-23-40	S B T	7.9 6.5 4.6	30 18 0		57 46 42	6 50 40	0.09 3.05 2.60	I = 0.24 A	W.L. ¾
8-26-40	S B T	7.9 6.2 4.8	29 14 1		58 45 42	6 50 40	0.10 2.85 2.65	I = 0.24 A	W.L. ¾
8-28-40	S B T	7.9 5.35 3.8	30 5 0		58 44 42	5 54 35	0.08 2.25 1.90	I = 0.24 A	W.L. 0 Beck.
8-30-40	S B T	7.9 6.6 4.4	30 17 0		59 47 43	6 50 35	0.09 2.80 1.60	I = 0.24 A	W.L. ½ Beck.
9- 4-40	S B T	7.8 5.9 3.8	30 9 0		58 44 42	6 50 40	0.10 2.40 1.85	I = 0.24 A	W.L. ⅔
9- 6-40	S B T	7.6 5.3 4.6	27 8.0 0		56 45 42	10 55 40	0.28 3.15 2.10	I = 0.24 A	W.L. ⅔
9-16-40	S B T	7.9 5.2 3.8	25 6.5 0		55 41 42	6 65 45	0.08 3.40 2.20	I = 0.24 A	W.L. 0 Beck.
9-18-40	S B T	8.0 5.3 4.2	26 4 0		55 41 43	6 70 50	0.05 3.20 2.60	I = 0.24 A	W.L. ⅞ Beck.
9-20-40	S B T	8.1 6.1 4.4	27 9.5 0		55 42 44	6 55 45	0.05 3.60 2.80	I = 0.24 A	W.L. ¾ Beck.
9-23-40	S B T	7.9 6.6 4.1	28 11.0 0		54 44 41	6 60 50	0.09 3.40 2.60	I = 0.24 A	W.L. ⅔
9-25-40	S B T	8.1 6.3 4.0	29 10 0		56 42 43	5 65 45	0.07 3.20 2.40	I = 0.24 A	W.L. ¾
9-27-40	S B T	8.0 6.7 4.0	28 14.5 0		55 44 43	5 75 40	0.08 3.80 2.20	I = 0.24 A	W.L. ⅞

Date	Sample	pH	M.O. alk.	CO_2	Soap hardness	Color	Total iron	Current	Note
9-30-40	S	7.8	28		57	6	0.8	E= 2.5 V	W.L. 0
	B	4.5	2		41	75	3.65	I= .01 A	
	T	3.5	8		42	40	2.25		
10- 2-40	S	7.8	28	0.0	57	6	0.09	I= .01 A	W.L. 2/3
	B	8.8	26		48	55	6.30		
	T	6.8	19	2.5	44	18	0.50		
10- 4-40	S	7.8	28	0.0	57	5	0.09	I= .01 A	W.L. Full
	B	7.9	24	0.7	47	200	17.50		
	T	6.0	20	1.8	43	15	0.48		
10- 7-40	S	7.9	29	0.0	58	6	0.07	E= 5.0 V	W.L. 2/3
	B	8.8	31	0.0	55	45	1.70	I= .0045A	
	T	8.7	28	0.0	59	10	0.20		
10- 9-40	S	8.5	30	0.0	58	5	0.06	I= .0045A	W.L. 1/2
	B	9.0	32	0.0	62	25	1.05		
	T	8.7	29	0.0	61	10	0.35		
10-11-40	S	8.4	29		57	5	0.08	I= .0045A	W.L. 7/8
	B	8.7	31		60	30	4.15		
	T	8.5	29		59	13	0.65		
10-14-40	S	8.2	28		56	5	0.08	I= .0045A	W.L. 3/4
	B	8.7	29		53	25	1.10		
	T	8.6	29		51	10	0.60		
10-16-40	S	8.3	28		55	5	0.07	I= .0045A	W.L. 1/4
	B	9.0	29		53	38	1.35		
	T	8.7	29		56	12	0.50		
10-18-40	S	8.3	27		54	5	0.07	I= .0045A	W.L. 1/2
	B	8.8	29		55	35	1.40		
	T	8.5	28		55	13	0.55		
10-21-40	S	8.25	27		53	6	0.06	I= .0045A	W.L. 1/2
	B	8.75	30		58	65	3.85		
	T	8.35	28		56	30	1.35		
10-23-40	S	8.30	27		54	5	0.06	I= .0045A	W.L. 3/8
	B	8.85	29		58	60	3.05		
	T	8.40	28		55	25	1.10		
11- 8-40	S	8.00	24	0.00	51	6	0.09	I= .0045A	W.L. 1/2
	B	8.55	26	0.00	52	40	1.75		
	T	8.00	25	0.00	51	20	1.30		
11-13-40	S	7.90	23	0.00	50	6	0.09	I= .0045A	W.L. 3/8
	B	8.55	26	00.0	52	30	1.05		
	T	8.00	24	0.00	51	20	1.10		
11-15-40	S	7.90	23	0.00	50	6	0.11	I= .0045A	W.L. 0
	B	8.50	25	0.00	52	35	1.40		
	T	8.05	26	0.00	52	20	1.15		
11-18-40	S	8.00	23	0.00	50	6	0.09	I= .0045A	W.L. 0
	B	8.50	25	0.00	52	45	2.15		
	T	7.50	21	0.00	49	20	1.15		
11-20-40	S	7.90	21	0.00	49	6	0.11	I= .0045A	W.L. 1/4
	B	8.45	25	0.00	50	40	1.95		
	T	7.50	20	0.00	46	18	0.96		
11-22-40	S	7.90	20	0.00	49	6	0.11	I= .0045A	W.L. 3/4
	B	8.45	25	0.00	51	40	1.80		
	T	7.60	19	0.00	46	30	0.90		
11-25-40	S	8.50	21	0.00	50	6	0.10	I= .0045A	W.L. 4/5
	B	8.70	25	0.00	53	45	2.20		
	T	8.45	21	0.00	51	20	1.10		
11-27-40	S	8.00	20	0.00	50	6	0.10	No current	W.L. 0
	B	8.50	23	0.00	53	40	2.35		
	T	6.60	16	0.00	47	20	1.80		
12- 3-40	S	8.00	22	0.00	51	6	0.13	No current	W.L. 1/5
	B	8.90	26	0.00	54	40	2.60		
	T	8.90	26	0.00	51	23	2.05		

At time of sampling, note was made of the height of water in 8½-inch surge line. Tank filled when reaching 8½-inch level.

Sample: S = Water from city main. B = Bottom of tank. T = Top of tank. pH determinations made with roulette comparator. Beck. = Beckman electrolytic.

Samples taken at various intervals, but tank was filled 4-6 times per day and current applied unless noted.

and the cathode. Since the acid radicals of the salts in solution do not escape from the solution, the potential at the anode will remain nearly constant during the electrolysis, and the potential at the cathode at the decomposition point is equal to the potential which the precipitating metal would itself have in the solution. Suppose a metallic electrode is dipped into water containing a solution of one of its salts in which the osmotic pressure of the ions is p. There will be a certain tendency for the metal to go into solution as ions, called the electrolytic solution pressure, which will be designated by P. Suppose that P is less than p, as must be the case if the metal stands below hydrogen in the electrolytic single potential difference scale. A certain amount of the ions of the metal will then be deposited on the electrode, charging the solution negatively and the electrode positively. The metallic ions in solution will then be repelled by the positively charged electrode with a force k, increasing with the quantity of metal deposited. The force finally becomes so great that equilibrium is established according to the following equation:

$$P+k=p$$

The potential difference between the electrode and solution is then given by the equation

$$(1) \qquad e=\frac{RT}{nF}\log_e\frac{P}{p}$$

where R is the gas constant, T the absolute temperature, n the valence of the metal, and F the electrochemical constant.

Supposing now the force k is diminished slightly by applying an external electromotive force in a direction tending to deposit the metallic ions on the electrode. The value of e will be changed only slightly from that given by the equation above, but the metal will be deposited continuously, because the sum of the forces P and k tending to send the metal in solution is now slightly less than the force p, tending to cause the metal to deposit. As the ions of the metal become more dilute, P becomes less, and the potential difference e, as well as the decomposition voltage of the solution, will consequently increase in value. The potential difference between the solution and the cathode eventually becomes so great that the value necessary for the deposition of hydrogen is reached. This potential difference, e_h is given by the equation:

$$(2) \qquad e_h=\frac{RT}{F}\log_e\frac{PH_2}{PH+}+n$$

where n is the overvoltage of hydrogen on the metal depositing. After this condition has been reached, the metal and hydrogen are deposited simultaneously. The following relation then holds as long as the electrolysis continues:

$$(3) \qquad e=\frac{RT}{nF}\log_e\frac{P}{p}=\frac{RT}{F}\log_e\frac{PH_2}{PH+}+n$$

If electrolysis is continued, the overvoltage n gradually increases, due to the increasing proportion of the current used to liberate hydrogen, and consequently p become less. It is evident that the reduction can never be absolutely complete for if p=0, e would be infinite

TABLE III — All Results Expressed in Parts per Million

Date	Sample	pH	M.O. alk.	Soap hardness	Color	CO_2	Total solids	Current	Note
7-25-41	S	7.9	32	40	60	0.00		E=8 V	W.L. ½
	B	7.9	32	40	60	0.00		I= .10A	
	T	5.7	20	38	60	0.00			
7-26-41	S	8.5	40	48	35	0.00		I= .10A	W.L. ¼
	B	8.5	40	48	35	0.00			
	T	5.9	24	38	35	0.00			
7-28-41	S	8.1	42	58	10	0.00		I= .10A	W.L. ¾
	B	8.1	36	38	60	0.00			
	T	5.5	26	40	60	0.00			
7-29-41	S	7.9	40	50	10	0.00		I= .10A	W.L. 2⅛
	B	6.9	30	36	50	0.00			
	T	5.0	18	38	50	0.00			
7-30-41	S	7.9	42	52	10	0.00		I= .10A	W.L. ½
	B	6.9	30	42	40	0.00			
	T	5.3	20	46	30	0.00			
7-31-41	S	7.9	42	48	12	0.00		I= .10A	W.L. ½
	B	6.4	28	52	35	0.00			
	T	5.9	32	38	25	0.00			
8- 1-41	S	8.1	44	54	15	0.00		I= .10A	W.L. ¾
	B	6.5	32	44	25	0.00			
	T	6.1	26	40	25	0.00			
8- 5-41	S	8.1	26	50	15	0.00		I= .10A	W.L. ⅛
	B	6.5	40	38	60	0.00			
	T	6.1	26	34	30	0.00			
8- 8-41	S	8.1	44	48	20	0.00	77	I= .10A	W.L. ½
	B	6.1	28	38	35	0.00	382		
	T	6.1	26	32	30	0.00	65		

At time of sampling, note was made of the height of water in 8½-inch surge line. Tank filled when reaching 8½-inch level.
Sample: S=Water from city main. B=Bottom of tank. T=Top of tank.
Samples taken at various intervals, but tank was filled 4-6 times per day and current applied unless noted.

TABLE IV — All Results Expressed in Parts per Million

Date	Sample	pH	M.O. alk.	Soap hardness	Color	CO_2	Total solids	Current	Note
8-11-41	S	7.9	44	48	7			E = 10 V	W.L. ¼
	B	5.1	22	48	35			I = .15A	
	T	5.5	28	52	35				
8-12-41	S	8.1	46	60	6		98	I = .15A	W.L. ¾
	B	6.0	36	50	30		100		
	T	5.9	38	52	35		108		
8-13-41	S	7.9	38	58	8		81	I = .15A	W.L. ½
	B	6.0	28	32	40		85		
	T	5.7	28	66	40		78		
8-15-41	S	7.9	38	56	8	0.00		I = .15A	W.L. ½
	B	6.5	30	46	30	14.00			
	T	5.5	30	60	30	23.00			

At time of sampling, note was made of the height of water in 8½-inch surge line. Tank filled when reaching 8½-inch level.
Sample: S = Water from city main. B = Bottom of tank. T = Top of tank.
Samples taken at various intervals, but tank was filled 4-6 times per day and current applied continuously.
Carbon electrode installed 8-9-41.

It is evident from equation (1) that to reduce the quantity of metal in solution to a negligible amount the increase in voltage at the cathode will be 0.23 volt for a monovalent metal, or half this value for a bivalent metal. Monovalent and bivalent metals must therefore stand respectively 0.23 volt and 0.12 volt below the potential at which hydrogen would be deposited on the side of the tank in question in order to be completely separated from the water. In consequence of overvoltage and of the possibility of reducing the concentration of hydrogen ions, the potential difference at which hydrogen is deposited may, under certain conditions, be very much greater than that given in the table of electrolytic potentials. Consequently, metals standing above hydrogen in the electrolytic series can be deposited in case the over-voltage of metal in question is high and the concentration of the hydrogen ions is low. This partially explains why in practical installations of cathodic protection, calcium and other salts are deposited on the tank walls. It is evident from what has been said that hydrogen plays an important role in electrolysis. It acts as a safety valve in preventing the potential difference at the cathode from rising above a certain value. This value depends on the concentration of the hydrogen ions and on the overvoltage. The reason the impurities or various salts in solution are not deposited when dilute is that the voltage drop from solution to cathode has not reached the decomposition point of these ions. The decomposition point of an ion changes with its concentration by the amount 0.058/n volt at 17C where n is the valence of the metal, for a change in concentration of the ion in the ratio of 1-10. As the concentration of any given ion increases, its decomposition point is gradually lowered until it equals the potential difference between the solution and the cathode or tank wall. At this point it is deposited with the hydrogen. As the color still remained high, as in Table III, using a stainless steel electrode, a carbon electrode furnished by the Rusta Restor Company was used in a series of experiments, as shown in Table IV. As expected the color due to iron in solution, when using a stainless steel electrode, decreased when the carbon electrode was used but an increase of carbon dioxide was found. On dipping a carbon electrode into a solution, the pores become filled with the solution, and the solution contained in the electrode is electrolyzed as well as that on the surface; but since the dissolved salt cannot be replaced in the pores as rapidly as in the solution on the surface of the electrode, the solution contained in the pores becomes more dilute than on the surface. This dilution can account for various side reactions in practical installations. The porosity of carbon electrodes varies from 11 to 28 per cent.

In these experiments the dilution factor of the experimental unit and the one-half million gallon stand pipe is approximately 1 to 13,500; this taken into consideration, the increase in color, total iron, etc., would produce a concentration of these substances which would not be objectionable in our water supply. However in other water supplies used to supply certain industries this increase might be objectionable.

In both of the experimental setups used, only one negative lead was used, namely one connected on the bottom of the tank; as expected the greatest deterioration of the electrodes occurred on the bottom of the electrode nearest the bottom. At the top of the surge line the tank was not as well protected from rust as the rest of the tank. In practical installations this condition is taken care of by using several negative leads, one of which is made near the top of the tank, or the negative discharge is equalized through the tank by using suitable resisting negative leads.

The amount of current used in a small experimental unit does not differ a great deal from that used for large industrial installations; the difference is one of overcoming the resistance offered by the water to the passage of the current, but the dilution factor of the various salts in solution, such as iron, does have a tremendous importance.

Conclusions: These experiments confirm the results obtained in the field of practical installations, namely, that the electrolytic protection of water systems is positive and practical. It is recognized that the change in constituents depends on the type of water used, amount of voltage, and amperage used, temperature, and the kind and concentration of salts in solution. Boiler feed water received from a system protected by the cathodic system will still require further treatment such as the addition of boiler compounds before admission to the boilers, especially when a carbon electrode is used. It is possible that with the use of cathodic protection troublesome elements such as iron and manganese may be removed at the time that protection to the system is applied.

BRUSHES and Brush APPLICATION

By W. H. Beyerle

ASSISTANT SUPERINTENDENT

ELECTRICAL DEPARTMENT

Bethlehem Steel Company

SPARROWS POINT, MARYLAND

Presented before A. I. S. E. PHILADELPHIA DISTRICT SECTION, April 4, 1942

. . . . brush application for satisfactory commutation may require trial and error experiments, with the plant serving as testing laboratory . . . .

▲ LET us review briefly the fundamentals of proper performance of brushes on commutating equipment. We are assuming that this equipment is well designed in every respect, both electrically and mechanically; and that the correct brush to make a perfect combination with the machine is provided.

The brush must naturally have sufficient current carrying capacity, good shunt connections whether riveted or cemented, mechanical strength to withstand shocks caused by uneven commutator surface and chemical properties that will enable it to withstand operating temperatures.

These properties must be so combined or processed that injurious sparking under reasonable loads does not exist. The abrasive ingredients must be controlled so that commutator wear is at a minimum. The brush must be able to form and preserve a uniform film over the surface of the commutator which is not too thick or too thin. This is the most important characteristic because energy losses due to selective action may become serious if the film is too thick, and friction losses increase when the film is too thin or is removed entirely. If these requirements are met, the brush should operate without noise and long life can be expected.

Figure 1 is a diagrammatic representation of brush performance which, regardless of the cause, is generally manifested by arcing. The latter is of four types, namely: arc, streamers, spit fire and pin fire. Operators and maintenance men are familiar with all of these. The first sketch is known as black commutation; the second and third as pin fire. These are not destructive, although some brush material is lost. The balance of the sketches show conditions that are progressively worse and when these conditions exist the apparatus must be given immediate attention, otherwise low brush life and a burnt or blackened commutator will result.

Figure 2 shows a chart that was taken from a brush manufacturer's bulletin and sixty-one sources of unsatisfactory brush performance are listed.

The first three are very common causes and are diffi-

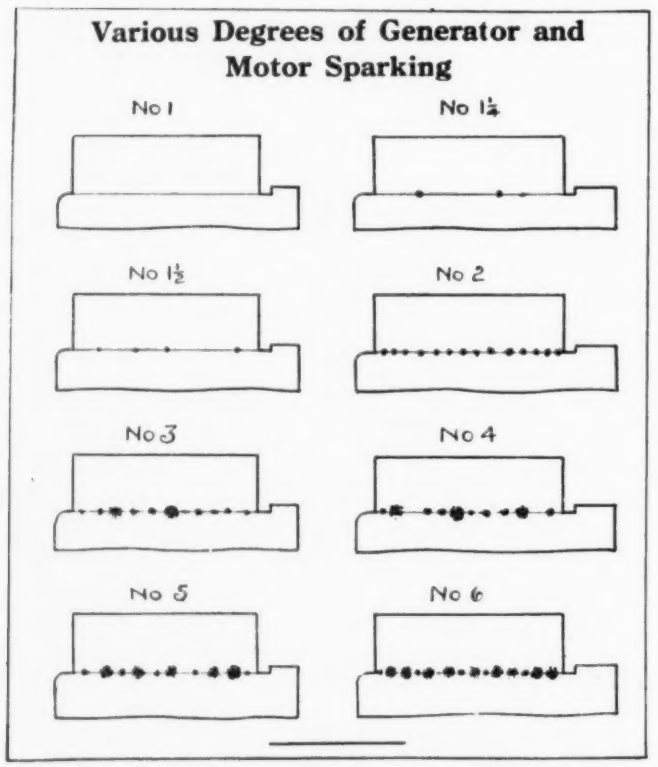


Figure 1 — Diagrammatic representation of brush performance showing various degrees of sparking.

Figure 2 — Chart showing sixty-one sources of unsatisfactory brush performance.

PRIMARY SOURCES OF UNSATISFACTORY BRUSH PERFORMANCE

Preparation and Care of Machine
✔1. Poor preparation of commutator surface
✔2. High mica
✔3. Feather-edge mica
4. Bar edges not chamfered after undercutting
5. Need for periodic cleaning
6. Clogged ventilating ducts

Machine Adjustment
7. Brushes in wrong position
8. Unequal brush spacing
9. Poor alignment of brush holders
10. Incorrect brush angle
11. Incorrect spring tension
12. Interpoles improperly ad usted
13. Series field improperly adjusted

Mechanical Fault in Machine
14. Brushes tight in holders
15. Brushes too loose in holders
16. Brush holders loose at mounting
17. Commutator loose
18. Loose pole pieces or pole face shoes
19. Loose or worn bearings
20. Unequal air gaps
21. Unequal pole spacing
22. Dynamic unbalance
23. Variable angular velocity
24. Commutator too small

Electrical Fault in Machine
✔25. Open or high resistance connection at commutator
26. Poor connection at shunt terminal
27. Short circuit in field or armature winding
28. Ground in field or armature winding
29. Reversed polarity on main pole or interpole

Machine Design
30. Commutating zone too narrow
31. Commutating zone too wide
32. Brushes too thin
33. Brushes too thick
34. Magnetic saturation of interpoles
35. High bar-to-bar voltage
36. High ratio of brush contact to commutator surface area
37. Insufficient cross connection of armature coils

Load or Service Condition
✔38. Overload
✔39. Rapid change of load
40. Reversing operation of non-interpole machine
41. Plugging
42. Dynamic braking
✔43. Low average current density in brushes
✔44. Contaminated atmosphere
45. "Contact poisons" (See Modern Pyramids, No. 2)
✔46. Oil on commutator or oil mist in air
✔47. Abrasive dust in air
48. Humidity too high
✔49. Humidity too low

Disturbing External Condition
50. Loose or unstable foundation
51. External source of vibration
52. External short circuit or very heavy load surge

Wrong Brush Grade
53. "Commutation factor" too high
54. "Commutation factor" too low
✔55. Contact drop of brushes too high
✔56. Contact drop of brushes too low
57. Coefficient of friction too high
✔58. Lack of film forming properties in brush
✔59. Lack of polishing action in brush
✔60. Brushes too abrasive
✔61. Lack of carrying capacity

cult to correct because undercutting is a laborious, tiresome, eye-straining job and this form of exercise is not too popular with maintenance men.

The other fifty-eight are equally important and some of them will be mentioned later under brush applications.

There is one more cause at least which is not listed and that is the phenomenon known as threading of the commutator or rifling. According to authorities, it is caused by electrolytic action, whereby copper is carried from the commutator into the brush. Light loads make it more pronounced because friction is higher with such loads, brushes chatter more and more air, or electrolyte, is introduced.

This very annoying action takes place on commutators and generators on our 250 volt plant service on which there are constantly varying loads. Two methods for overcoming this action can be used: first, remove as many brushes as possible; and second, use a non-resilient type of brush.

We shall now pass on to some of the more interesting and severe applications in our plant:

Figure 3 shows a generator that belongs to a fly wheel motor-generator set. It drives a blooming mill, 7000 hp motor. Its rating is 3000 kw, 4600 amp, 600 volts, at 375 rpm. The load current peak frequently reaches 250 per cent overload for short periods of time. At one time, arcing was severe, brush life low and commutator maintenance high. Many grades of brushes from different manufacturers were tried on the generator and the

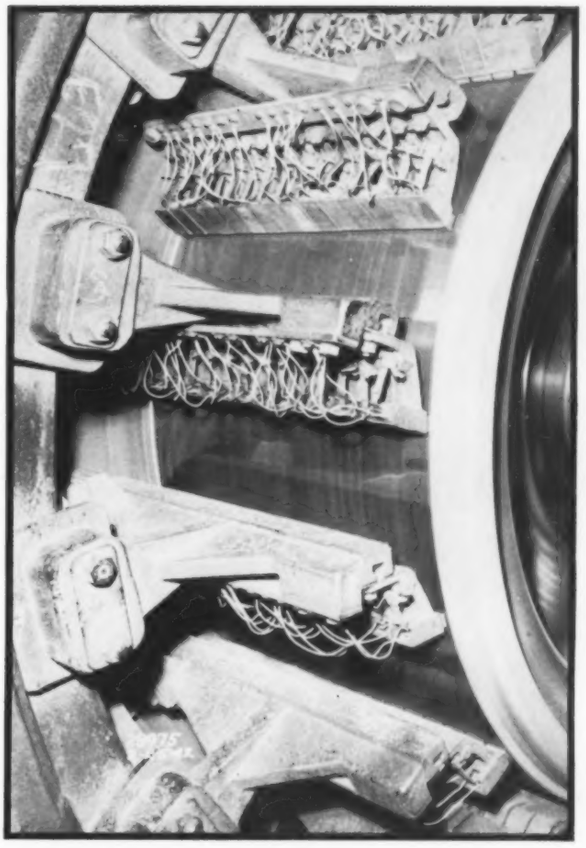


Figure 3 — Commutator of generator on which brush performance was improved by installing a set of split brushes.

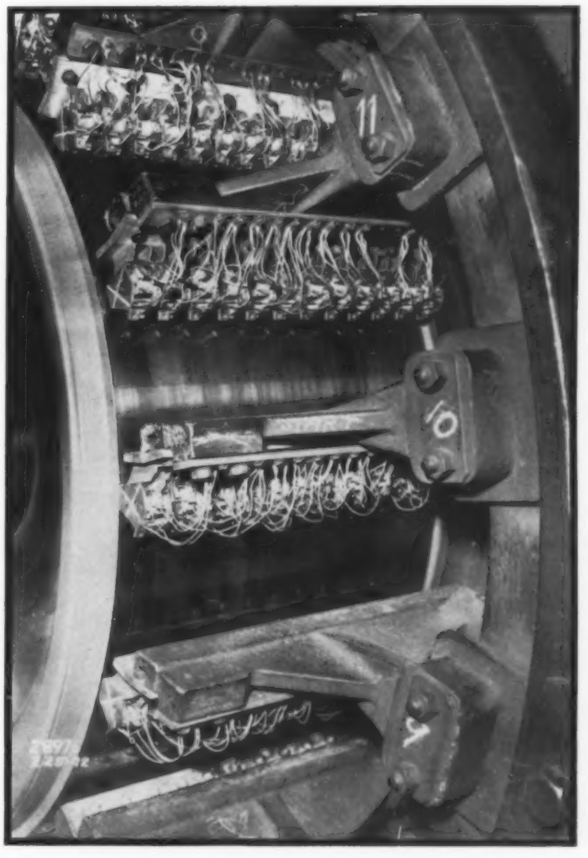


Figure 4 — Double brush holder arrangement, with one brush trailing 10 degrees bevel and the other leading 30 degrees bevel.

improvement, even with cleaner brushes, was far from satisfactory.

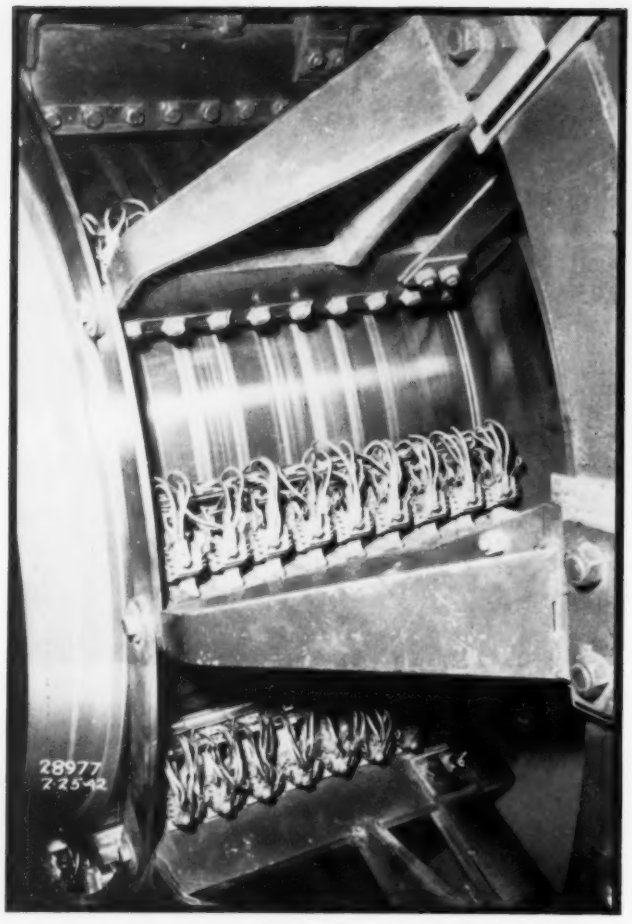
About two years ago a set of split brushes were installed in the old brush holders and the improvement in commutation was amazing. Brush life was increased 75 to 100 per cent and commutator maintenance was reduced to a minimum. In this instance it was definite proof that our previous difficulties were due principally to the mechanical arrangement of brushes and not to the grade used.

Figure 4 shows a generator which is of the same rating and service as the previous one and shows a double brush holder arrangement. The one on the left runs trailing 10 degrees bevel on the commutator and the one on the right runs leading 30 degrees bevel on the commutator. This arrangement is satisfactory and the commutator is in excellent condition.

Figure 5 is a generator that is rated 3000 kw, 5000 amp, 600 volts at 360 rpm.

The brushes are arranged in parallel in the same box with a narrow strip of metal separating them. The service in this application is also severe and we are now experimenting with different grades of brushes in an attempt to secure better commutation with good brush life.

Figure 6 shows the steel collector rings in the field



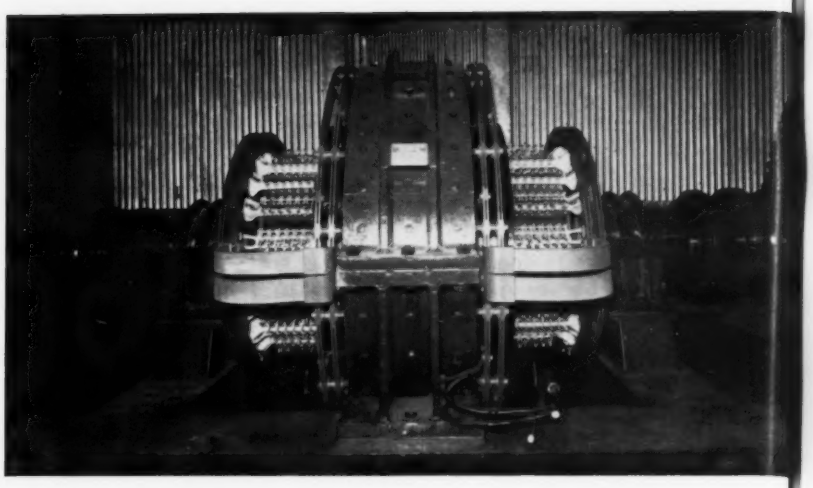


Figure 5 — View showing brushes arranged in parallel in the same box with a narrow strip of metal separating them.

Figure 6 — Steel collector rings in field circuit of 8600 hp synchronous motor, using helical grooving in the rings.

circuit of an 8600 hp synchronous motor, 360 rpm, the feature being the helical grooving in the rings. This is our first installation and for four years no brushes have been changed and no rings serviced.

This brings up a very pertinent question about helical grooving of commutators on heavy duty motors and generators. There are some strong advocates who claim very interesting results are obtained and that the disadvantages caused by the work necessary to groove commutators are considerably over-weighed by the advantages.

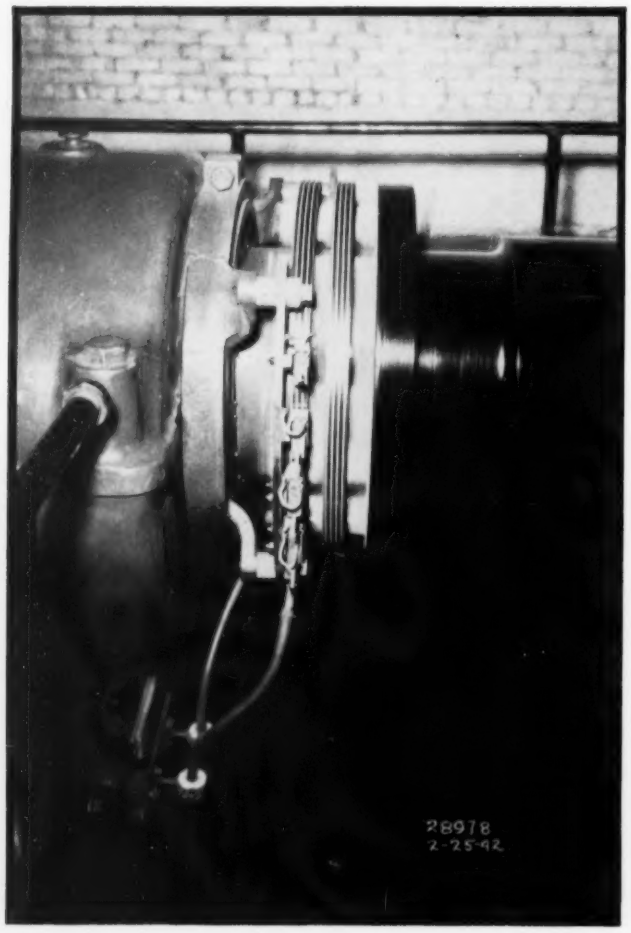
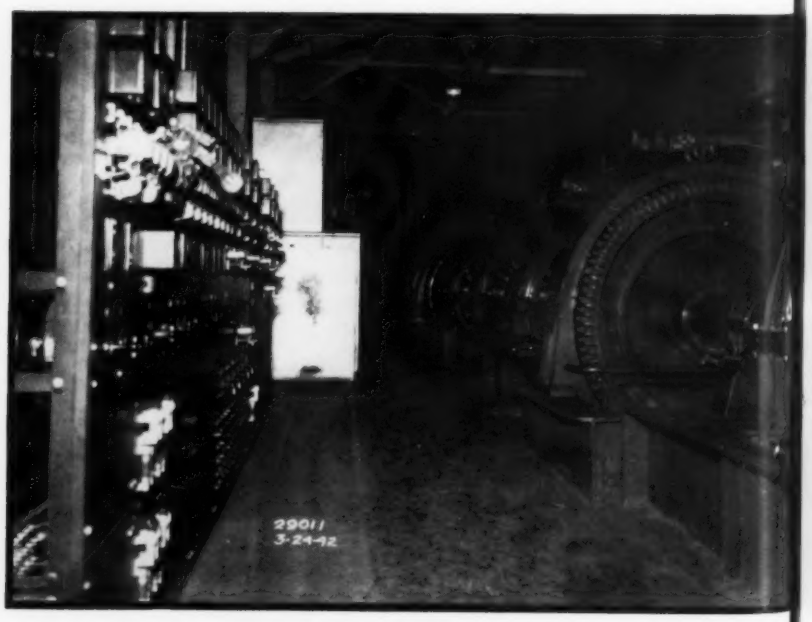


Figure 7 — Metal graphite brushes operate at a current density of 60 amp per sq. in. in this 36 volt, 7500 amp plating generator.

Figure 8 — In cold weather steam is introduced in ventilating air to increase humidity for satisfactory performance of metal graphite brushes.



I shall quote from a paper on helical grooving of slip rings and commutators, by Robert Walker Goodman, of Sidney, Australia, who claims the following:

"The advantages of grooving are:

1. It tends to force a much better distribution of current both in the brush face and between parallel connected brushes.
2. It greatly reduces heating and sparking at the brushes with consequent better overload capacity.
3. Gives increased brush life and reduces ring and commutator wear.
4. Provides a means of escape of air and gases that are trapped under the brushes.
5. Prevents local spot heating and consequent glowing under the brushes."

These statements seem to have foundation for on a test of a 1000 kw commutating machine, the rate of brush wear before grooving was 7000 hours per inch and after grooving was 12,600 hours per inch.

Figure 7 shows a 270 kw, 36 volt, 7500 amp plating generator. It is one of six used in our plant to deposit zinc on wire by the electrolytic process. The total current actually used is 48,000 amperes at voltages ranging from 20 to 30.

The brushes are metal graphite and operate at a density of 60 amperes per square inch. Three of these generators have undercut mica and three have flush mica commutators.

These generators operate night and day, seven days a week and have run for 6 months without a shut-down. All maintenance on the brushes must be made while the generators are in service.

Figure 8 is a view of the two motor-generator sets used in the aforementioned plating process. They are driven by two 1750 hp synchronous motors.

This equipment is ventilated by air which is forced through a tunnel under these machines. In freezing weather, steam is introduced to increase the humidity to a point at which the brushes will function satisfactorily. Metal graphite brushes require a certain amount of moisture to be in the surrounding atmosphere for satisfactory performance, otherwise they will disintegrate very rapidly.

In view of the fact that electrical equipment is designed for severe and special service, such as blooming mills, continuous mills, etc., where the peak loads reach two to three times the normal rating of the machine for short periods of time, the customer has every right to believe that the manufacturer has provided the best brush obtainable through consultation and cooperation with the brush manufacturer.

After a machine is first installed, we find occasionally that the choice of brushes was not entirely satisfactory from a commutation or life standpoint or both. The usual procedure is then to start a trial and error experiment with brush manufacturers who are of necessity constantly developing new grades to meet modern demands; but in the final analysis the industrial plant must serve as a testing laboratory. This method is expensive but unavoidable if better performance is pertinent. In some applications, it is necessary to choose between the smaller of two evils: better commutation with reduced brush life or better brush life with more commutator maintenance.

For general purpose applications, brush catalogues will furnish sufficient information to make a proper selection comparatively easy.

We, in the maintenance game, have the responsibility of following with intelligent study and alertness the problems influencing the successful performance of brushes.

Maintenance of Hydraulic Equipment

By G. C. Pfeffer, SUPERINTENDENT OF POWER

Florence Pipe Foundry & Machine Co.

FLORENCE, NEW JERSEY

Presented before A. I. S. E. PHILADELPHIA DISTRICT SECTION, April 4th, 1942

▲ THIS subject of maintenance of hydraulic equipment is such a broad one that the time allowed will permit the mentioning of only one or two of the main causes of high maintenance of hydraulic systems, therefore, the speaker has selected two items:

1. Shock, or water hammer, as it is better known.
2. Contaminated systems.

In order that we may have a mutual understanding of the term "shock," we will use the definition of shock, as given to us in non-technical terms by several recognized authorities on hydraulic systems.

Water, oil, or any liquid, traveling at high velocity will exert a powerful force, depending on its volume and speed. This mass cannot be stopped without a time allowance, any more than your car can be stopped by driving it into a stone wall without doing considerable damage.

We find some comparable reactions between a car striking a solid obstacle and shock in a hydraulic system. The hood of a car after striking a solid object, is pleated or built up in layers like an accordion. So it is with water when striking a dead-end or high resistance. These layers will build up and expand all surrounding parts until the pressure at this point is sufficient to start the flow moving in the opposite direction.

If it were possible to stop this water or fluid instantaneously — and all parts containing it were non-elastic — the maximum speed of the reversed flow would be close to 4700 ft per sec, and the pressure would be approximately sixty-three times the velocity. However, as it is impossible to close a valve without a lapse of

time — and as all pipe lines, cylinders and etc. are elastic — the aforementioned figure will never be as bad as shown. These facts are mentioned merely to show that it is not unusual to find a pressure increase of two or three times greater than the original pressure.

When installing a hydraulic system, in order to avoid excessive maintenance, the elimination of shock should be one of the major considerations. The installation of air bottles and shock valves will greatly reduce water hammer or shock. These should be installed not only close to the machine, but as well, in the pipe lines, whether the pressure is 150 psi or 5000 psi.

A shock or water hammer can be caused by a large quantity of fluid of low pressure moving at a low velocity, with a result equal to that produced by a small quantity of fluid of high pressure moving at a high velocity. Another cause of shock is the valve. A few years ago, pressure of 1500 psi were considered high. The machines were usually of a slow moving type. Operating valves were of the piston type, and spring loaded valves were installed in the pipe lines to reduce shock. All in all, they did a pretty good job.

Today, however, pressures are much higher, 5000 psi being quite common. Machines are operating at much higher speeds, with the result that shocks in pipe lines have become more serious in their effect, and failures never heard of before are occurring.

A case the speaker heard of some time ago, might be worth mentioning, as it will illustrate just what can happen. During World War I, a certain manufacturer was engaged in making shells by use of hydraulic machinery. Operating pressures were around 2000 lb, and the machines were of a rather slow speed. Devices such as shock valves or air bottles were not used, and apparently they had little trouble. Recently this same concern again started the manufacture of shells, but they had replaced the earlier slow operating presses with those made for greater speed, using welded pipe lines in place of flanged pipe lines. In short, they had a very nice installation, except for one oversight; there were no shock valves or air bottles to take care of shock in the lines. Shortly after the machines were placed in operation, things began to happen — pipe lines broke, cylinders on the machines broke, and troubles became quite numerous. After a careful survey, shock valves and air bottles were added, and trouble ceased.

It has been learned that if the exhaust lines are kept filled, it tends to cushion shock. We have found in recent installations that a pressure of 50 to 100 pounds in the exhaust lines tends to reduce shock, but it is important that the unit be designed with sufficient back pressure to permit it.

Another very effective method to reduce shock is to bleed the high pressure in the machine down to a lower pressure, before opening the main valve to exhaust. This in many cases can be incorporated in the main valve design. The delay incurred, or the time required to bleed down the pressure, will be considerably less than one second.

Piston type valves are being replaced by valves that restrict the flow gradually, and which can be operated at higher pressures easily and without the use of a long lever.

Accumulators too small for the work to be done, are often the cause of shock. Here we have a large weight traveling down at a high rate of speed suddenly stopped, resulting in a terrific blow. This can be relieved by inserting an orifice in the discharge line from the accumulator, or installing an accumulator throttle valve.

In designing the pipe lines, care should be taken to make them large enough, and provisions should be made so that the lines can be cleaned of foreign material such as weld splatter, scale, etc., by the removal of one or more sections.

The old hydraulic systems which were developed as the hydraulic load increased cannot be cured by the few suggestions offered here, any more than a doctor has a cure-all for his patients. Shock valves, air bottles and air accumulators must all be well located to give proper results. If you have a system giving trouble, consult someone familiar with this subject.

If water is used, see that it is free from sand. Many times it is found that the source of supply is badly contaminated. Strainers should be installed in the lines near the machines to be operated. If the oil is used, as found in a closed system, it should be filtered from time to time, — say, once every six months, dependent of course, upon the service.

Just one more thought that should not be overlooked. Lubrication of rams and packings should be given regular and careful attention, as it is of vital importance. In closing, let me leave these thoughts with you. Provide ample means to prevent shock, . . . and keep the system clean.

TIN SUBSTITUTES PROVE SATISFACTORY IN BRONZES

By J. F. Pelly and John Worth

Bethlehem Steel Company

BETHLEHEM, PENNA.

▲FOLLOWING the receipt early in 1942 of War Production Board's Conservation Order M43A, the operating and purchasing departments of the Bethlehem Steel Company undertook to reduce the consumption of tin in babbitts, bronzes and solders used in its plants for maintenance purposes.

As the first step, a survey was made of the alloys in use at that time. After determining the type and amount of an alloy used in a given application, the possibility of using a lower tin substitute was considered.

Tin-Bronze Bearings

In the case of bronzes containing lower tin, it was decided that an elaborate experimental program to precede any widespread use would be unnecessary, because their physical properties were well known and composi-

tions could be selected which were quite comparable in properties to the higher tin alloys.

A chart of recommended substitutes was distributed to all of the plants. It is recognized that some of the substitute compositions are not standard with the industry and, therefore, are not readily available in ingot form. They were designed to suit conditions peculiar to our plants where we had to make the most economical use of home scrap. Of course, any of these compositions can be produced from standard commercial ingots by making the necessary additions.

In one of our plants the substitute bronzes have been in use since June 8th apparently with satisfactory results as no failures have been reported to date. We might cite one instance where the substitute material has actually given better service than the material it replaced. On the main shaft bearings of a structural mill hot saw, bearings of Cu 85, Sn 3½, Zn 5, Pb 5, Ni 1½ have lasted longer than the Cu 90, Sn 10 formerly used.

We are also investigating the possibilities in the use of silicon and aluminum-bronzes. However, to date we have only a few experimental installations.

Babbitt Bearings

In the past our plants have been using tin-base babbitts containing from 80-90 Sn and lead-base babbitts containing 5-10 Sn. Service tests are now being made to replace tin-base babbitt with two low tin substitutes. One of these is an arsenic-lead-base babbitt and the other a silver-lead-base babbitt. Their compositions are as follows:

	Pb	*Sb*	*Sn*	*Cu*	*As*	*Ag*
Arsenic-lead-base	bal.	12.5	.75	...	3.	...
Silver-lead-base	bal.	10.	3.	.2	...	2.6

Arsenic-lead-base babbitts are under test in the following locations:

1. Crank pin box on blast furnace gas blowing engines.
2. Pinion boxes on 8 in. bar mill.
3. Pinion boxes on 9 in. bar mill.
4. Pinion boxes on 160 in. plate mill.
5. Tube mill welding roll bearings.
6. Main bearings on scrap preparation shears.
7. Jack shaft bearings on ore transfer cars.
8. Connecting rod bearings on air compressor.
9. Bearings on high-speed fans
10. Bearings for general-purpose electric motors.

Silver-lead-base babbitt is being tested in a crank pin box on one of our large mill engines.

The use of these substitutes is being rapidly extended. Care should be taken not to contaminate arsenic-lead-base babbitt with tin-base babbit. This means that all babbitt scrap must be carefully segregated. In this connection we are adopting a color code system of identification which will be applied to all bronzes and babbitts.

In the meantime, while tests are being made on the new babbitts, a major saving in tin is being effected through use of the lead-base babbitt containing only 5-10 per cent Sn wherever possible.

Solder

As the use of tin in solder is also covered in Conservation Order M43A, we have discontinued the use of solders containing over 30 per cent tin. Our tests have shown that a solder of the following composition has been found satisfactory for general purposes, including electric motor commutators:

Lead	77.75
Tin	20.00
Silver	1.25
Bismuth	.50
Antimony	.50

For wiping purposes, however, 70 lead, 30 tin solder is considered somewhat more satisfactory.

RECOMMENDED SUBSTITUTES FOR STANDARD TIN BRONZES

Present composition						Application	Tensile strength	Yield strength	Elongation	Brinell hardness	Substitute composition						Application	Tensile strength	Yield strength	Elongation	Brinell hardness	Remarks
Cu	Sn	Zn	Pb	Ni	P						Cu	Sn	Zn	Pb	Ni	P						
90	10	....	....	½	0/1.00	Bearings, bushings, nuts, gears.	50,000	23,000	30	72	88	5½	4	½ Max.	2½	0/0.05	Bearings, bushings, nuts, gears, pressure castings.	42,000	17,000	32	75	Heavy duty.
....	....	....	....	....	.....	.....	.....	.....	.....	.....	85	3½	5	5	1½	0/0.05	... .	36,000	15,000	30	71	Light and medium duty.
80	10	....	10	. .	0/1.00	Bearings, bushings, feed nuts.	38,000	18,000	30	62	76	6	1	16	1	0/0.05	Anti-friction bearings.	29,000	16,000	18	60	Heavy duty.
....	....	....	....	....	.....	.....	.....	.....	.....	.....	85	3½	5	5	1½	0/0.05	Bearings, bushings, feed nuts.	36,000	15,000	30	71	Light and medium duty.
85	5	5	5	....	.....	Bearings, bushings, nuts, pressure castings.	34,000	15,000	32	53	85	3½	5	5	1½	0/0.05	Bearings, bushings, nuts, pressure castings.	36,000	15,000	30	71	Light and medium duty. (If higher hardness not objectionable.)
88	10	2	....	....	0/0.05	Pressure castings, bearings, nuts, gears.	45,000	19,000	30	65	88	6	4½	1½	½	0/0.05	Pressure castings, bearings.	38,000	17,000	28	55	Not suitable above 500° F. Medium duty.
88	8	4	....	....	0/0.05	Pressure castings, bearings, nuts, gears.	45,000	19,000	30	58	88	5½	4	½ Max.	2½	0/0.05	Bearings, pressure castings, nuts, gears	42,000	17,000	32	75	Heavy duty.
....	....	..	....	..	.....	.....	.....	.....	.....	.....	85	5	5	5	.....	0/0.05	Bearings, pressure castings, nuts, gears	34,000	15,000	32	53	Light duty.
60	....	40	....	....	.....	Light duty application. (No wear.)	25,000	12,000	15	.....	....	.....	.....	.....	.....	.....	....	... ...	.. ....	.....	.....	No substitute.

NOTE: All physical values are typical and should not be interpreted as minimum or maximum.

DEVELOPMENTS *in* NON-FERROUS *Bearing Metals*

. . . . non-ferrous bearing metals are all on the wartime critical list . . . . substitutions are imperative . . . . care must be exercised in design and maintenance in order to obtain maximum life . . . .

By H. A. White

National Bearing Metals Company

Pittsburgh, Pennsylvania

Presented before A. I. S. E. SPRING CONFERENCE
Hamilton, Ontario

▲ WATCHING the development of non-metallic resinous bearings and roller bearings and their expanding use in the modern steel mill has made many a bearing foundryman have serious misgivings as to the future of his business. Unfortunately, the complacence and technical ignorance of many brass foundrymen had probably considerable to do with bronze bearings being outmoded in many applications where they could more economically be used today. Intelligent engineering design and the use of metallurgically correct bronze or babbitt alloys or both coupled with greatly enlightened knowledge of lubricants and lubrication we feel sure can effect a satisfactory and less costly solution to many bearing problems. Bronze and babbitt occupy an important place in the steel mill.

With comparatively few exceptions brass founders have been content to accept orders for bearings to be made to customers' patterns and specifications without the knowledge or will to ascertain their suitability for the intended application. It is our feeling that with research effort such as has been expended on non-metallic and roller bearings, the steel mill engineer will have a more comprehensive fund of knowledge from which to draw the proper selection of the best kind and type of bearing to do the job.

In this discussion, we must necessarily generalize and will try to acquaint you with the basic alloys both of bronze and babbitt, their analyses and physical properties, a few precautions in bearing design and operation, in the hope that some of your bearing problems may be solved thereby.

As you know, the components of the non-ferrous alloys, copper, tin, lead, aluminum, etc. are all on the wartime critical list, and substitutions are becoming imperative. However, we will ignore these shortages and proceed on the basis of normal supply and in conclusion will offer some remarks on substitutions.

Bronze

Bearing bronzes are in general copper-tin matrices filled with lead. The term bronze, by definition applies strictly to copper-tin mixtures as differentiated from brass which indicates copper-zinc mixtures. These terms are very loosely used and it is quite common to speak of bronze bearings as "brasses." On the other hand we speak of manganese bronze, Tobin bronze, etc. which are in reality brass, and aluminum "bronze" which contains neither tin nor zinc.

The committee on Bearing Metals of the American Society of Mechanical Engineers some years ago gave an excellent explanation of why bronze should be used in preference to brass for bearing purposes. In the case of a bronze bearing metal of 90 copper, 10 tin, we secure a mixture of at least two dissimilar crystals and possibly three. In the case of copper and zinc, only one set of crystals is formed, up to a high zinc content. A homogeneous mass is formed as contrasted with the non-homogeneous mass of hard and soft elements in the copper-tin alloy, and the latter mixture is desirable because of the formation of the minute oil reservoirs. The shop man will tell you that, in a bearing, brass is

dry and harsh as compared with bronze, and it is undoubtedly the property of providing oil cells that gives bronze its value as a bearing metal.

The majority of copper-tin bearings contain less than 12 per cent tin and combine hardness with ductility. They are limited to service where alignment is good, as they do not possess sufficient plasticity to conform readily to a shifting load. They find use in some machine-tools and similar equipment, where good alignment may be maintained, and are used abroad on some railroad equipment, where speeds and pressures are not excessive and where fitting is carefully performed. With ideal service conditions, a copper-tin bearing will probably outwear bearings containing added metals, but in most classes of service localized pressures caused by changing alignment will produce rapid wear and heating in this composition. Zinc is sometimes added to copper-tin mixtures and the familiar gun-metal is composed of 88 copper, 10 tin, 2 zinc, but the most widely used bearing mixture is the copper-tin-lead bronzes.

In bronzes containing lead, we have the reservoir-forming property further enhanced. The lead does not combine with the copper-tin structure, but is only mechanically held by it in the form of globules. It imparts plasticity to what would otherwise be a more or less rigid structure, in addition to furnishing it with additional oil reservoirs.

There are several so-called standard bronzes. A tabulation of the more commonly used S.A.E. specifications are given in Table I.

There are many variations and many grades of quality of each of these alloys. In the steel mills S.A.E. 64 or 80-10-10 is probably the most widely used bearing bronze. The addition of from .25 to 1.00 per cent phosphorus will considerably enhance the physical properties particularly the hardness. Machining becomes increasingly difficult as the phosphorous content is raised — the structure of the metal is more open. Contrary the requirements of many bearing users, an open structured metal is often not undesirable for bearing bronze. A certain degree of porosity will permit the absorption of the lubricant without the loss of too much bearing surface. If .5 to 1.00 per cent nickel is added to an 80-10-10 bronze, the resultant alloy has a tough fibrous

TABLE I

S.A.E. Bronze Specifications

Alloy	Composition	Treatment	Tensile strength, psi	Per cent elongation
S.A.E. No. 40 Red brass	84-86 Cu, 4.0-6.0 Sn, 4.0-6.0 Pb, 4.0-6.0 Zn, 0.25 max Fe, 0.25 max Sb, 0.75 max Ni.	Castings — sand	27,000	15
S.A.E. No. 43 Manganese bronze	55-60 Cu, 38-42 Zn, 1.5 max Sn, 0.40 max Pb, 3.5 max Mn, 1.5 max Al, 2.0 max Fe	Sand cast Chill cast	65,000 70,000	25 20
S.A.E. No. 62 Bronze	86-89 Cu, 9-11 Sn, 0.2 max Pb, 1-3 Zn	Sand cast	30,000	14
S.A.E. No. 63 Leaded gun metal	86-89 Cu 0-11 Sn, 0.25 max P, 0.5 An, 1-2-5 Pb	Sand cast	30,000	10
S.A.E. No. 64 Phosphor bronze	78.5-81.5 Cu, 9-11 Sn, 9-11 Pb, 0.05-0.25 P, 0.75 max Zn, 0.25 impurities	Sand cast	25,000	8
S.A.E. No. 65 Gear bronze	88-90 Cu, 10-12 Sn, 0.10-0.30 P, 0.5 max Pb, Zn	Sand cast	35,000	10
S.A.E. No. 67 Semi-plastic bronze	76.5-79.5 Cu, 5.00-7.00 Sn, 14.5-17.5 Pb, 4.0 max Zn, 0.4 max Sb, 0.40 max Fe, 1.00 max impurities	Sand cast	20,000	10
S.A.E. No. 68 Cast aluminum bronze	85-87 Cu, 7-9 Al, 2.5-4.5 Fe, 0.5 max Sn, 0.25 impurities	Sand cast	65,000	20

For high quality material impurities should be limited to .25 per cent.
Oxide inclusions are determinable by micrographic examination.
Standards for practical foundry production are not available.
However, modern melting practice and laboratory control should keep oxides below harmful level.

grain and its resistance to impact is considerably increased. It thus becomes an ideal alloy for the heavy loads and slow to moderate speeds of roll neck bearings. It will hold its lubricant even when the necks are flooded with water.

For lighter loads and applications not subject to end thrust, the cheaper alloys ranging down to 6 per cent tin and from 16 per cent lead upward, are quite satisfactory. They machine quickly and easily. In this broad class of alloys are included stock cored bars and sticks, machine bushings, crane bearings, etc. When used under proper loads, an important advantage is gained. On account of the relatively high lead content, short lubrication failures will not produce dangerous heating.

The addition of one per cent nickel to the leaded bronze, while causing foundry problems, produces a tougher alloy which is capable of taking more impact without squashing.

S.A.E. 62 is variously termed gun bronze, hydraulic bronze or 88-10-2; the two per cent is usually zinc, though sometimes, as in S.A.E. 63 the zinc is replaced with lead for the sake of lubrication. This is a widely used alloy of close dense structure. It is dense and also resilient and because it threads well, it is used for housing screw nuts, gears, liners and the like. Later we will discuss aluminum and manganese bronzes, but I would like to make the recommendation here that unless service is too severe, hydraulic is much to be preferred from a lubrication standpoint. Being dense it is also desirable for many types of valve bodies and parts and other castings which must withstand high pressures.

It has been found to be a very satisfactory bearing alloy for use under heavy load and slow rubbing speed in places where grit is excessive such as cement mills and crushers.

Another very widely used alloy is S.A.E. 40, more commonly known as red brass. It has excellent machineability and is suitable for valves, pump impellers and the like where pressures are not excessive.

With the advent of the wide strip mill and many other of the newer developments in the rolling of steel, it became necessary to use bronzes with much higher physical characteristics than the copper-tin-lead alloys. Out of this demand came the much wider use of a variety of so-called aluminum and manganese bronzes. S.A.E. 68-B is probably the best known. Its composition is 89 per cent copper, 10 per cent aluminum and 1 per cent iron. As cast in sand its tensile strength will range from 65,000 to 75,000 psi and it will Brinell about 120 under 3,000 kg load. This alloy has the further advantage of being one of the relatively few bronzes which will respond to heat treatment. Properly heat treated the tensile can be raised to the range of 85,000 to 95,000 psi and the Brinell to 160-180. Other aluminum bronzes range in composition from 1 to 10 per cent iron and from 5 to 15 per cent aluminum with varying physical characteristics.

S.A.E. 43 is only one of the many manganese bronzes, which as a group are really more properly described by the term yellow-brass since their basic composition approaches that alloy of 60 per cent copper and 40 per cent zinc. However, the addition of small percentages of aluminum, manganese and iron, completely changes its structure and manganese bronzes may be obtained having a range of tensile strengths from 60,000 to 105,000 psi and Brinell hardness numbers from 100 to 230 under 3,000 kg load. The main uses of the aluminum and manganese bronzes in the strip mill are for screw-down nuts and bearing segments or spindle slippers. As we stated previously, unless the application necessitates the high strength or hardness of one of these alloys, it is preferable to select one of the copper-tin lead series. We take this position from the standpoint of the lubricating problem involved. Unless practically perfect lubrication is provided, either of these dry, harsh bronzes will heat up rapidly with all the attendant trouble. Even very brief lubrication failures are almost sure to cause serious heating whereas the copper-tin-lead bronzes are safe for a time.

Heavy cuts in machining may seriously injure a bearing bronze. Some years ago trouble was experienced by heating in the driving-wheel bearings in new locomotives of one of the railroads. Our company had furnished the bearings and we were called upon to explain the trouble. Chemical analysis of the bronze was made and found satisfactory. The fracture revealed nothing to the naked eye, but when a machined section was polished and placed under the microscope it was apparent that heavy cuts in machining had actually forced a large part of the lead from the copper-tin sponge, and a rigid structure was the result. It was suggested that only $\frac{1}{8}$ inch cuts be machined from the bearing journal surface, to eliminate this distorted metal, and after this was done, no further heating was experienced.

Clearance should be allowed for the expansion of the roll in the direction of its axis. Where variations in temperatures are great, considerable friction may be caused by pressure of the roll fillet against the bearings and serious heating and consequent destruction of the latter will occur.

Crossed rolls are another source of trouble by producing high fillet pressures. The rolls tend to move axially in opposite directions and the bearings are called upon to take these thrusts. Often, new bearings are placed in old rolls and the roll neck having a smaller diameter must wear into the bearing quickly to distribute the pressure. On the other hand where new rolls are placed in bearings previously used on smaller necks, spreading of the bearing occurs, which may break it through the back, or which, at least, makes lubrication extremely difficult.

Care should be taken with lubricants for all classes of bearings, and the lightest one capable of withstanding the pressure encountered should be used, as needlessly heavy lubricants increase friction.

Too much care cannot be used in keeping out foreign matter. It is not an unusual occurrence for roll necks to show grooves two inches deep corresponding to the ridges of iron on the bronze. A small piece of scale usually starts the abrasion and successive layers of iron cut from the neck are deposited on the bearing.

The water used for cooling may be the unsuspected cause of trouble. In the Pittsburgh district the river waters at times contain considerable percentages of acids. Heating of bearing under these waters has not been explained, but may be caused by corrosion of the journal or the introduction of sulphur compounds be-

tween the surfaces. Electrolysis may occur, as an ideal electric battery is present, and occasional pitting of the bearings lends plausibility to this theory.

Babbitt Metals

As you know babbitt metal derives its name from its founder Isaac Babbitt. Mr. Babbitt would probably be more than surprised today to know how broadly his name has been applied to white metal alloys. It has been said that his discovery made the development of modern high-speed machinery possible. In the more than 100 years that have intervened, many wonderful mechanical developments have taken place. Widely varying conditions of strain, load and speed, such as Babbitt never dreamed of, are common to bearing services today.

To give you some idea of the proportions of babbitt business and the confusion which may arise in the selection of babbitt metals, we have a list of some 250 proprietary brands and there are undoubtedly many more, in addition to many specifications.

Babbitt's original formula is not exactly known but is approximately 89 per cent tin, 4 per cent copper and 7 per cent antimony and from it have been developed a host of mixtures ranging from even higher tin content clear through to almost straight lead. This breaks into two broad classes: (1) tin base babbitts, i.e. alloys containing more than 50 per cent tin, and (2) lead base babbitts, or those containing more than 50 per cent lead. It would be very impractical to discuss the hundreds of brands on the market or all of the many formulae in specifications.

However, a good practical range of babbitt metals is set up under A.S.T.M. specification B 23-26. These analyses and their physicals are given in Table II.

In a steel mill, a range of four babbitts for storeroom stock should be sufficient to cover most applications, with perhaps occasional additional grade to take care of some unusual service condition or requirement. In general the selection of grades 1, 4, 8, 12 should be satisfactory for storeroom stock.

The addition of antimony imparts hardness and is helpful in uniting with the tin. Copper or arsenic may be added to prevent the segregation of the lead. Nickel in fractional percentages will increase toughness in tin-base babbitts. In making the selection of a babbitt it will be helpful if the normal operating temperature is noted. Table III shows what happens to Brinell values at various degrees of heating.

It is important that impurities be limited in any specification since the absence of such limitation may open the way to the use of improperly cleansed and purified scrap in the manufacture, with its resultant melt loss and poor service. However, a poor quality of babbitt is not always the cause of bearing failure.

Good babbitt metal must be properly handled, preferably with a pyrometer to insure good results, and for successful babbitting, we suggest the following rules be closely observed:

1. Bearing boxes must be clean, dry and warm.
2. Pouring must be done slowly and steadily, with a thin stream.
3. Babbitt must be at the proper temperature when pouring.
4. The metal should be stirred well, and dipped from

TABLE II

A.S.T.M. Babbitt Metal Specifications

Alloy No.	Formula, per cent				Deformation of cylinder 1¼ in. diameter by 2½ in. high at 70 F, in.			Brinell hardness		Melting point	Complete liquation point	Proper pouring temperature
	Copper	Tin	Antimony	Lead	At 1000 lb	At 10000 lb	At 5000 lb	At 70 F	At 212 F	Degrees F	Degrees F	Degrees F
1	4.5	91.0	4.5	.....	0.0000	0.015	0.001	28.6	12.8	437.0	699.8	824
2	3.5	89.0	7.5	.....	0.0000	0.0020	0.0015	28.3	12.7	460.4	683.6	808
3	8⅓	83⅓	8⅓	.....	0.0010	0.0070	0.0045	34.4	15.7	462.2	791.6	916
4	3.0	75.0	12.0	10.0	0.0005	0.0090	0.0025	29.6	12.8	365.0	555.8	680
5	2.0	65.0	15.0	18.0	0.0010	0.0090	0.0030	29.6	11.8	365.0	536.0	661
6	1.5	20.0	15.0	63.5	0.0015	0.0180	0.0050	24.3	11.1	365.0	512.6	638
7	.....	10.0	15.0	75.0	0.0010	0.0230	0.0050	24.1	11.7	464.0	500.0	625
8	.....	5.0	15.0	80.0	0.0020	0.0620	0.0090	20.9	10.3	469.4	500.0	625
9	.....	5.0	10.0	85.0	0.0040	0.0840	0.0120	19.5	8.6	469.4	491.0	616
10	.....	2.0	15.0	83.0	0.0010	0.1540	0.0100	17.0	8.9	473.2	500.0	625
11	.....	.....	15.0	85.0	0.0010	0.1190	0.0100	17.0	9.9	476.8	500.0	625
12	.....	.....	10.0	90.0	0.0025	0.2850	0.0170	14.3	6.4	476.8	509.0	634

For high quality material impurities should be limited to .25 per cent.

TABLE III

Babbitts — Brinell Hardness Numbers

	Sn	Cu	Sb	Pb	Room[1]	100 F[1]	212 F[2]	250 F[2]	300 F[3]	350-F[3]
1	90	4	5½	.....	25.9	22.3	14.7	11.6	9.2	6.7
2	87	6	7	.....	27.8	23.8	14.2	12.2	9.2	7.6
3	89	4	7	.....	23.8	20.5	10.9	10.1	8.1	5.7
4	65	5	8	22	20.9	17.2	10.7	8.3	6.6	4.3
5	40	4	10	46	18.6	15.9	9.7	7.2	5.2	2.75
6	30	3	10	57	21.4	17.5	10.1	7.7	3.8	*
7	15	1	13	71	25.9	17.8	14.2	10.6	9.0	6.3
8	5	.....	15	80	18.2	17.2	11.9	10.1	8.1	6.0

*Metal too soft to test. [1] 500 kg load, 10 mm ball. [2] 250 kg load, 10 mm ball. [3] 100 kg load, 10 mm ball.

below the surface when ready for use.

5. Mandrels should never be allowed to become excessively hot, as pouring on a very hot mandrel will sometimes cause the babbitt, when taken off, to crack.
6. We especially caution against the addition of other metals or salvaged babbitt, because the perfect amalgamation of a good babbitt is likely to be destroyed thereby.
7. Generally speaking, the proper pouring temperature for high grade tin base alloys, is when the dipping of a white pine stick will ignite it, and when so tested, lead-base babbitts will brown a white pine stick, but as mentioned above a suitable pyrometer or babbitt thermometer is much more reliable.

The melting should take place slowly, and with frequent stirring, and we always advise customers to have the same person do the babbitting if possible, for the reason that our experience proves they become familiar enough to tell, by the appearance of the alloy, when the proper temperature is reached. It is also advisable to heat the babbitt as close to the work as possible; otherwise, if it must be carried any great distance, it is necessary to overheat it in order to have the proper temperature when pouring is done.

A ladle sufficiently large to hold all the metal to pour the entire bearing at once time should be used, if practicable, as it is better to have a little more than not enough.

As soon as the metal begins to melt, the surface should be covered with powdered charcoal. This will retard the formation of scum or dross. When the babbitt has reached the pouring temperature, the bearing should be heated somewhat. This evaporates any slight moisture which may be in the bearing, and which would cause blisters in the babbitt; it also prevents sponginess in the babbitt, which would be caused by hot metal coming into contact with cold.

When the babbitt has reached the pouring temperature, it should be stirred thoroughly, first removing any surface scum.

The success of the operation depends in a great measure upon the method of pouring. After dipping from below the surface, the pouring should be done slowly, in order to obviate the loss of any metal should the mandrel be loose, and with a thin steady stream, as a thick stream, which entirely fills up the hole, causes air pockets to be carried down, producing holes in the bearing. The object of a thin stream is to permit the escape of the air which is in the bearing. A broad or intermittent stream will also cause seams or blow holes.

An air pocket may seem a minor defect, but it really is a serious matter, especially if oil happens to get into the pocket. Being directly connected with the oil film the pocket as a general rule, will fill with oil, and oil does not carry away the heat of friction as rapidly as babbitt or iron. When the bearing heats slightly the oil becomes hot, because the babbitt lining will retain, instead of throw off the heat. Continual running in this condition will result in constantly melting the babbitt out of the bearing. Unless proper equipment and supervision familiar with refining secondary metals are available, it is usually more advisable not to attempt the re-use of babbitt. Generally it is more economical to dispose of run out babbitt and buy new. It should be borne in mind however that the various grades should be kept carefully separated to insure the maximum return when it is sold.

Combination Bearings

There are two general classes of roll neck bearings which combine the use of both bronze and babbitt.

Commonly, for blooming mills, plate mills and the like, the bearings are constructed by the use of a steel shell into which babbitt is poured. Two or more bronze strips or a grid are set into the journal surface. It is usually necessary to use a high grade babbitt for this purpose. However, the present emergency precludes the use of high tin content metals. Here is one case where a change can be offered which should prove to give better service than the bronze grid bearing. It is in effect the reversal of bronze and babbitt. It will be

found that a properly designed bronze bearing, cast of a high grade nickel bronze and having several babbitt-filled pockets in the journal surface, is a distinct economy. The following are from actual rolling mill records:

1. In a 34 in. blooming mill: were using babbitted shells with two bronze grids which had to be relined at two week intervals with babbitt loss of 50 to 60 per cent. These replaced by bronze bearings with babbitt pockets.
   1st set — Nine months continuous service, 188,000 tons rolled.
   2nd set — 147,000 tons rolled. Bearings set aside for later roll change.
   3rd set — 132,000 tons rolled and still in service.
2. In a 38 in. blooming mill: were using babbitted shells with two bronze grids. Each relining averaged 70 per cent babbitt loss. Bronze bearings put in service July 1. Checked August 31.
   3/16 in. wear in journal and 3/16 in. in fillet. Checked October 8 — 136,000 tons rolled, 1/4 in. wear in journal, 1/8 in. wear in fillet. December 15 water connection on mill broken. Bearing ran hot to cracking point, 250,000 tons rolled, 3/8 in. wear in journal, 1/2 in. wear on fillet.
3. In a 34 in. blooming mill: bronze bearings installed June 14, 1941. Report March 25, 1942 — constant service, 329,000 tons rolled with 1 in. wear, equivalent to 7 or 8 babbitt relinings.

The bearing design is fully as important as correct and high quality bearing material to avoid costly shutdown and failures. Excellent notes on bearing design and lubrication are usually to be found in good handbooks. There are several precautions to be observed in designing bearings:

1. Provision for sufficient heat radiation.
2. Care that oil grooves are placed so as not to break oil film in pressure area.
3. Lubricant feeding points should be away from pressure area.
4. Proper clearances allowed both in journals and fillets for formation of lubricant wedge.
5. Avoidance of sharp bearing edges, which may act as lubricant wiper.
6. Remember that too much bearing is source of useless friction loss. Arc of content should the least possible consistent with length to secure necessary projected bearing area.

Conclusion

In conclusion we will try to give a brief resume of War Production Board restrictions, their effect and possible substitutions in the steel mill.

Probably the tin conservation order is the most far reaching in up-setting normal bearing procedure. As the order now stands, unless further amendments have been made during the last few days, we can supply bearing metals with a tin content of not over 12 per cent on a preference rating of A-3 or higher. This means that the normal bearing bronzes need not be changed. Tin cannot be used for any other than bearing metals excepting as an integral part of "implements of war." Silicon bronzes are, at the moment the most widely used substitute. We do not, however, recommend silicon bronze for use as a bearing metal, until such time as the copper-tin-lead alloys are unobtainable. Babbitt, of course, is limited as well, to a maximum of 12 per cent tin. As yet, we do not know of a "just as good" substitute for the genuine and tin base babbitt metals. The closest approach is 12 per cent tin, 2 per cent copper, 12 per cent antimony and the balance lead. The difference in price as compared to genuine babbitt will help in a measure to offset the diminished service to be expected from the latter. If your babbitt bearings do not work satisfactorily on the lower tin content babbitt, the change over to bronze bearing as suggested earlier may prove to be the solution. Solder cannot contain over 30 per cent tin.

We are further restricted in the use of tin (except as we are able to get relief from the WPB) to 50 per cent of the quantity consumed in the corresponding quarter of 1940. In the interest of tin conservation and keeping your bearing metals as close to par as possible, it is extremely important to keep the scrap and borings of the copper-tin-lead metals carefully segregated from others so that they can be sold to a smelter or returned to your brass foundry in an uncontaminated state. In the past we have had thousands of pounds of otherwise excellent bearing metal scrap spoiled by having been mixed with even small quantities of aluminum, silicon or manganese bronze scrap. Therefore we cannot urge too strongly the use of great care to keep the scrap of your bearing alloys separated from other bronzes whose composition may be harmful.

The other non-ferrous metal restrictions, so far, have more effect on delivery than on composition. For instance, in order for us to get even the small percentages of aluminum or nickel for bronze, we must have a purchase on our books in time to apply to Washington by the fifteenth of the month for *permission to produce* the castings during the second month following.

Also the WPB is insisting on bronze foundries having a sixty day backlog of copper base alloy orders. This in effect means that we must have orders on our books at the latest by the 25th of May in order to receive allocations to produce your castings in July. (Note: WPB now requires A-1-k or better for the purchase of non-ferrous castings.)

We do not mean by this that you are to tie up a lot of bronze by ordering a large stock of non-ferrous metals, but rather that requirements be estimated and orders be placed about sixty days in advance of necessary delivery date.

In reporting practically all of the non-ferrous metals, it is necessary that we show the "end use" in some detail. It will be a great help both to your purchasing department and to the foundry if you will show on your requisition the end use (i.e. roll neck bearing, crane bearing, housing nut, etc.) also the total approximate or estimated weight of the castings and the date of actual need of them.

In closing, we cannot emphasize the absolute necessity of taking all possible precautions so that you will get the maximum service from all non-ferrous castings. See that all parts are in correct alignment, that they are being properly lubricated, and safeguard as much as possible against the entry of grit, scale or dirt onto journal surfaces. Then when the bearing is worn out take care of the scrap and see that it gets back into

circulation promptly again. By conscientiously following this procedure you will be contributing to the spirit of the conservation orders, irksome as they may sometimes seem, and aiding materially in our all-out war effort.

DISCUSSION

PRESENTED BY

L. F. COFFIN, Superintendent, Mechanical Department, Bethlehem Steel Company, Sparrows Point, Maryland

H. A. WHITE, District Sales Manager, National Bearing Metals Corporation, Pittsburgh, Pennsylvania

E. W. TREXLER, Superintendent, Mechanical Department, Bethlehem Steel Company, Johnstown, Pennsylvania

L. C. SENTANCE, Mechanical Engineer, Canadian Westinghouse Company, Ltd., Hamilton, Ontario, Canada

L. F. COFFIN: The subject of babbitts and bronzes used in steel plants as presented by Mr. White in such an excellent manner, deserves a great deal more attention than has been given to it. We have had in effect at Sparrows Point for some time, a general policy of using only two types of babbitt, one lead base and one tin base instead of the four types recommended. We have our own brass foundry and manufacture our bronzes and babbitts. The advantage of only two types of babbitt is that in re-melting (we do believe in re-melting) it is much more easy to keep the types segregated and to preserve the purity of the mix. In normal times, the use of tin base babbitt is restricted to extreme service applications, the great majority of our babbitt normally being lead base. At present, use of tin base babbitt is still further restricted.

We cannot agree with Mr. White when he recommends the change over of mill roll neck babbitt bearings from babbitt to bronze. In a 40 in. x 80 in. slabbing mill, we have eliminated the use of brass grids altogether. We use a lead babbitt roll neck bearing properly tinned into a cast steel shell. The last pair of bearings changed in that mill had rolled a tonnage of over 1,000,000 tons. We consider it highly important to properly tin the steel castings prior to pouring babbitt so as to increase the rate of heat transfer between the babbitt and the steel shell. This point is overlooked in many steel mill applications. I have heard of one interesting method recently of securing this same result by welding thin layer of bronze to the inside of the shell, then tinning it and then babbitting. This is believed to be a high grade job and to make it easy to rebabbitt without subsequent expensive tinning.

We have also experimented with metal spraying cast steel shells with tin and other compositions so as to endeavor to improve the heat transfer, but we have found that results were unsatisfactory. It is our belief that where ideal lubricating conditions such as proper oil film can be maintained, babbitt is to be preferred to bronze for heavy duty applications. An outstanding example of this is a modern oil film roll neck bearing which has become such a great competitor of the roller bearing. I would like to ask Mr. White whether he knows of any satisfactory lead base babbitt containing practically no percentage of tin and using an arsenic or other hardening agent that will stand continual re-melting without deteriorating and would satisfactorily replace heavy duty service tin base babbitt.

H. A. WHITE: I want to say first that my comments on steel mills not re-using babbitt stemmed from the observation in a good many plants that they were not properly equipped to handle the refining of secondary babbitt. As you no doubt know, a great deal of the babbitt that you buy is refined secondary metal. I don't know the proportions of that to primary metals, but I happen to know that Sparrow's Point, and a good many other steel mills have very excellent babbitt refining departments, where they can do probably just as good a job as the babbitt manufacturer.

However, as I say, my comment was directed at mills where I have seen some pretty sad instances of using run out babbitt without any attempt at refinement, and with the resultant inclusion of dirt and grit and one thing and another that is harmful to the relined bearing.

Now, as far as the lead base babbitts are concerned, where tin is eliminated entirely, there are one or two. The babbitts containing a small percentage of arsenic and those up to 13 to 14 per cent antimony, are, in a measure, satisfactory, but they do not come up to the

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genuine babbitts in service. At least our experience indicates that is going to be the case. In the steel mill proper we haven't yet had enough experience in these places where tin base babbitts have always been used to know just what the results are going to be.

I am not prepared at the moment to give a definite specification for the impurities and oxide inclusions in bearing metals, both bronzes and babbitts. A good bearing metal bronze specifications should not have more than .25 impurities, and the same would probably go for babbitt.

E. W. TREXLER: We are attempting to do the same thing that Mr. Coffin and everybody else is; that is, reducing to the absolute minimum the use of tin base babbitt and substituting lead base babbitt or other bearing metals. We hesitate to do this on certain types of bearings, such as crank pin bearings and motor armature bearings. Nearly all the steel plants are using tin base babbitt on their motor armature bearings.

I want to ask Mr. White what substitute he can recommend for the tin base babbitt in motor armature bearings.

H. A. WHITE: It is unfortunate that these substitutes seem to be undergoing the same fate as rapidly as they are made as the original metals.

We were experimenting with a babbitt containing upwards of 20 per cent of antimony and introducing a small content of phosphorus, when out comes an antimony limitation order, which cuts down the use of antimony to about 12 per cent, and we are trying out that metal at the present time.

The large babbitt manufacturers, I notice, have been advertising lead base babbitt recently, which they claim has physical properties approaching those of the tin base babbitt. I don't know the analyses of those babbitts but I suspect most of them are the arsenical babbitts and those are the ones we are going to have to fall back on, I believe, to weather this time of stringent control of all non-ferrous metals.

L. C. SENTANCE: Although I haven't had any experience with roll neck bearings, there are a few general points in Mr. White's talk about which I would like to question him. It has, I think, been generally conceded that the design of bearings is based on their performance on starting, stopping, or during periods of lubrication failure, rather than on their running performance. In this connection, Mr. White has pointed out that in the case of a 90 per cent copper, 10 per cent tin bearing bronze, superior performance to that of brass bearings is obtained, due to the fact that in the structure of the former metal at least two dissimilar crystals are obtained, allowing formation of minute oil reservoirs.

There is a tendency on the part of certain writers to discount the effect of metallographic structure of bearing metals, and they base their conclusions on successful tests made on pure bearing metals, such as lead, silver, bismuth, and cadmium. Is the advantage of bronze due to that particular property mentioned by Mr. White, or is it due to the relative weldability of tin and zinc?

Metals such as aluminum, copper, magnesium and zinc exhibit a strong tendency to weld to the shaft when it comes in direct contact with the bearing materials, while lead and tin exhibit this tendency to a considerably lesser degree. Is then the advantage of bronze due to the formation of oil reservoirs, or to the fact that tin is a constituent of the bronze bearing, while brass contains copper and zinc?

There is one other point in connection with the subject of babbitts which I think might be mentioned — the use of lead silver babbitts. These have been publicized quite a lot and claims have been put forth that these particular babbitts can be used in place of tin base babbitts in practically all applications.

The silver content of these new babbitts varies from 2 per cent to 6 per cent, with approximately 10 to 15 per cent antimony, and the remainder lead.

H. A. WHITE: As far as the metallurgical theories of the value of various alloys for bearing metals are concerned, there are several theories and which is the correct one I am certainly far from prepared to say.

Regarding the silver babbitt, I don't know anything about those. I understand there is being considerable work done on them and there is probably no doubt that silver will come into use during the emergency for many purposes in replacing not only tin, but possibly in plating for nickel and chrome.

While of course we will have to dispose of our preconceived ideas of silver being one of the precious metals, there is no question but what it will form an excellent alloy with lead. Now, whether it will be as serviceable as tin, I don't yet know.

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Sizes No. 14, 16 and 18 A. W. G. in two to six conductors with 12¼, 25 or 31 mil wall of felted asbestos insulation and cadmium plated steel armor.

A multi-conductor control wire for low voltage intercommunicating, signal and temperature control systems. Its lifetime insulation and rugged steel armor will give you troubleproof circuits.

600 VOLT ALL-ASBESTOS RHEOSTAT CABLE—TABLE R

(Underwriters' Type AI)

Sizes No. 18 A. W. G. to 1,000,000 CM insulated with a heavy wall of felted asbestos, covered with a rugged asbestos braid finished in black, white or colors.

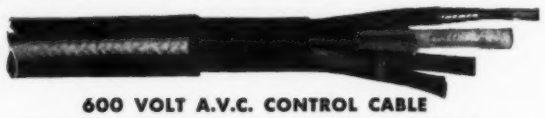
Use this power and rheostat cable for wiring rheostats, switchboards, elevator and locomotive control panels and electrical equipment exposed to heat, fumes and fire hazard. Also for general open wiring in dry, high temperature locations. For solid conductor specify Rockbestos Rheostat Wire, Table A.

600 VOLT A.V.C. MOTOR LEAD CABLE—TABLE L

(Underwriters' Type AVA)

Sizes No. 18 A. W. G. to 1,000,000 CM insulated with two walls of felted asbestos and a high-dielectric, heat-sealed varnished cambric insert, covered with heavy asbestos braid.

Heatproof, fireproof, greaseproof and oilproof, this cable will not dry out and crack, won't burn or carry flame, and will remain permanently flexible. For coil connections, motor and transformer leads where extreme heat and fire hazards are encountered as in steel mills, boiler rooms, etc.



600 VOLT A.V.C. CONTROL CABLE

In one to 19 conductors. Standard stranding A. W. G. No. 12—19/No. 25 and No. 9—19/No. 22. Other strandings furnished.

Designed for use under conditions too severe for control cables with other types of insulation which deteriorate rapidly when exposed to high temperatures. Operates without failure under the attack of heat, oil, grease or corrosive fumes and may be installed in conduit as it has ample moisture resistance.

600 VOLT A.V.C. POWER CABLE—TABLE E

(Underwriters' Type AVA)

Sizes No. 18 A. W. G. to 1,000,000 CM insulated with laminated felted asbestos and varnished cambric, and asbestos braid. Other constructions for service voltages up to 8000.

This cable is recommended for power circuits and hot spot wiring in or around boiler rooms, ash pits, steam tunnels, soaking pits, tenter frames, glass plants, steel mills, etc. The asbestos and heat-sealed varnished cambric construction has ample moisture resistance and withstands high temperatures indefinitely.

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ROCKBESTOS

The Wire with Permanent Insulation

New DEVELOPMENTS in LUBRICANTS for STEEL PLANTS

. . . . improvement of lead naphthenate extreme pressure lubricants and development of a new high temperature oil help solve industrial lubricating problems . . . .

By Maurice Reswick, ENGINEERING DIVISION
Standard Oil Company of Pennsylvania
PITTSBURGH, PENNSYLVANIA

▲ THE metal industry is the backbone of our all-out-for-victory program. Our steel mills must keep on unceasingly to turn out plates for ships and tanks, billets for shells, while our forging plants are called upon to produce armor plate and guns in ever increasing quantities. The non-ferrous industry is busy turning out aluminum sheets for airplane construction and the brass rolling mills are engaged in turning out cartridges for shells.

Of equal importance with metals in present day warfare, is petroleum and its derivatives, as a motive power for ships, airplanes, and mechanized equipment and for lubrication, not only on the far flung battle fronts, but also in the rolling mills and metal work shops at home. Higher rates of production, heavier loads, higher temperatures in rolling steel have imposed new demands on the petroleum industry. This paper covers the highlights of some of the latest developments in the petroleum industry to meet these requirements, and to solve the dual problem in the steel mills of high pressure and high temperature operation.

Extreme Pressure Lubricants

The introduction of extreme pressure lubricants in the steel industry took place with the advent of the continuous 4-high mills. It was found that the pinions driving the work rolls must of necessity be limited in size, with consequent high unit loads on the gear teeth. At these high pressures, rising at times to over 10,000 lb per inch of face, straight mineral oils did not provide a sufficiently strong film, and the situation was saved by resorting to fluid lubricants having from 5 to 7 times the film strength of mineral oils. With the first 4-high mills a success at the capacity for which they were built, mill operators began to take heavier reductions at higher speeds, and it was found that the life of the roller bearings on the back-up rolls was shortened. Again resort was made to greases containing extreme pressure ingredients to save the situation. At present most rolling mills built in recent years are lubricated with extreme pressure oils and greases.

With the mills on war production and the difficulty of procuring spare parts, such as gears and bearings, the subject of extreme pressure lubricants assumes more importance, if existing equipment is to be made to last, and wear on the gears and bearings eliminated or greatly reduced. Gears and bearings must now transmit still greater loads at even higher speeds to keep the flow of ship and tank plate without interruption.

An extreme pressure lubricant bears the same relation to a straight mineral oil as an alloyed steel bears to straight carbon steel — the addition of compounding or alloying agents results in increased strength and serviceability in both cases. For industrial applications experience has shown that the most satisfactory extreme pressure lubricant today is one in which lead soaps are incorporated in a properly selected blended oil.

Lead oleate, which is essentially metallic lead converted into a soap in a manner similar to that of making ordinary soap by saponifying the metal sodium with certain fats, has been in use for a long time as an extreme pressure ingredient. The majority of the new continuous mills in operation at present are lubricated with such products; but these require special attention and periodic inspection, as the base oil suitable for lead oleate lubricants are inherently susceptible to oxidation as evidenced by an increase in viscosity over a period of time. The usual correction is to use a lighter viscosity of the same material for cut-back purposes. Because of their inherent soap character, lead oleate extreme pressure lubricants have also a tendency to

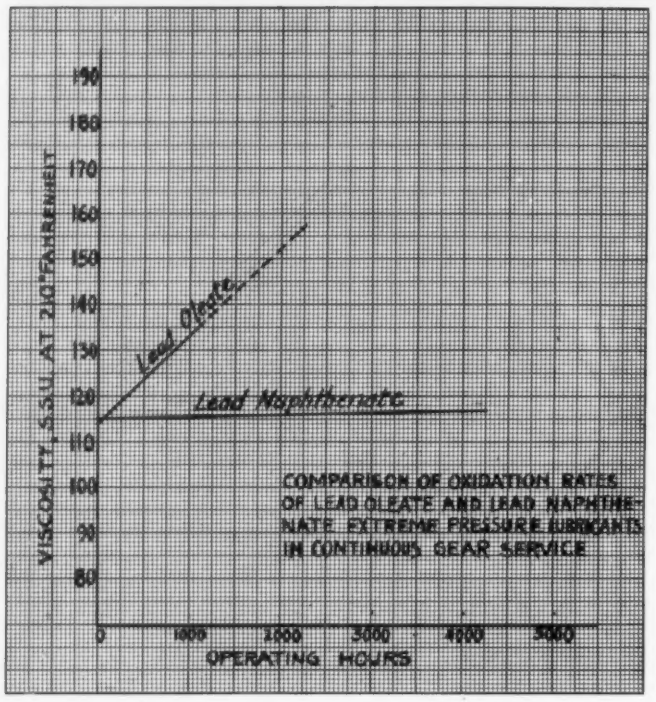


Figure 1 — Curves showing comparison of oxidation rates of lead oleate and lead naphthenate extreme pressure lubricants.

absorb water and to foam in the presence of moisture. Despite these disadvantages, they have a remarkable record of performance and are in extensive use throughout the rolling mill industry, and no difficulties are encountered so long as their limitations are recognized and they are serviced properly.

Lubricants which depend on lead naphthenate as the effective extreme pressure ingredient have been known and used for some time, but these have the inherent disadvantage of lower load carrying capacity as compared with lead oleate type lubricants. It was only recently that it was found possible to improve these lubricants by combining the lead naphthenate with other ingredients which results in greater film strength.

Lead naphthenates are soaps made up with metallic lead and naphthenic acids, preferably derived from certain petroleum crude . When of petroleum origin, they are perfectly soluble in petroleum oil, and the lead naphthenate is therefore completely miscible in the base oil. Furthermore, proper selection and blending of the base oil also results in imparting to the lubricant outstanding properties of resistance to oxidation, reduction of foaming and decreased susceptibility to absorption of moisture. These advantages have been gained with the retention of adequately high load carrying capacity.

Figure 1 compares the difference in the rate of oxidation of lead oleate and the new type lead naphthenate extreme pressure lubricants, based on actual performance in gear drives, against extended operating hours.

Figure 2 shows the variation in viscosity with temperature for the new type lead naphthenate lubricants. The curves are for fluid lubricants having approximate viscosities of 50, 70, 90, 110, 130 and 150 sec Saybolt universal at 210 F. This chart serves the purpose of selecting the correct viscosity of these extreme pressure lubricants at 100 F or 210 F and in determining its viscosity at any other temperature.

The real criterion of the efficacy of an extreme pressure lubricant is its record of plant performance, but a relative indication may be obtained by means of laboratory testing machines. There is a number of such testing machines, but the one which is best known to users of extreme pressure lubricants on industrial (as distinguished from automotive) applications is that developed by the Timken Roller Bearing Company. In this machine shown in Figure 3, the outer race or "cup" of a Timken roller bearing of 6 in. circumference is rotated at 800 rpm or at a surface speed of 400 fpm against a rectangular steel block, with a flow of the test lubricant directed at the rubbing contact area. The load is applied on the steel block by means of a lever and fulcrum, and the machine is run for 10 minutes. Then the condition of the cup and test block is noted. If there is no "pick-up" of metal or scoring of the block, another new surface of it is turned up and a new cup is used for another test at a heavier load. If there is evidence of failure, the test is repeated with a lighter load. The condition of the test block for an O.K. and for a score load is shown in the illustration.

The Timken Roller Bearing Company defines a satisfactory extreme pressure lubricant as one that will carry a minimum of 33 lb O.K. load on the lever without scoring either the rotating cup or the test block, and this definition receives general recognition among users of such lubricants.

The Timken machine is also used for determining the abrasion properties of extreme pressure lubricants. The procedure is to weigh the test cup and test block before and after running the machine for 6 hr at a load of 20 lb on the lever. The combined loss in weight of the cup and block in milligrams is taken as a measure of the abrasiveness of the lubricant. The significance of this test is to detect the presence of abrasive matter, such as asbestos, coarse graphite, etc. The Timken Roller Bearing Company regards an abrasion loss not exceeding 40 milligrams as indicating a satisfactory lubricant from the standpoint of wear.

It is the practice of the Timken laboratories to test lubricants at fixed arbitrary loads of 25, 33, 51, 59, 68 and 77 lb, beam load only, and to disregard any intermediate loads. In other words, should a lubricant carry a load of 58 lb for 10 minutes but fail at 59 lb, it is rated as having an O.K. load of 51 lb. Also should a lubricant carry an O.K. load of 59 lb for 9 minutes and fail before the prescribed 10 minute interval, it is regarded as having failed to pass the test at that load.

It must be realized, however, that the test results on any lubricant testing machine are at best correlative and sometimes only indicative. Laboratory testing machines aim to duplicate actual operating conditions as close as possible, but it is obvious that a cylinder rubbing against a flat surface does not reproduce exactly the rolling and sliding action of meshing gears or the rotation of a shaft in a sleeve bearing. It is not safe, therefore, unless a high degree of correlation with actual test results has been established, to adjudge one lubri-

cant superior to another just because it carries more weight on the testing machine. The results may be reversed if the machine is operated at a different speed, or the order of merit changed if another type of testing machine is chosen as the criterion of comparison.

It is also possible to obtain a high rating on a testing machine by including more or less chemically active additives, but these may result in the pitting and corrosion of machine parts. For long time industrial use, an extreme pressure lubricant must have adequate load carrying capacity, and freedom from corrosion, oxidation, foaming, and settling out of the ingredients in the form of sludge.

It is generally known that the heavier the oil is in body, or viscosity, the higher lubricating film strength it possesses. Figure 4 shows the relation of film strength to viscosity as determined on the Timken lubricant testing machine, for straight non-compounded mineral oils. A comparison between a straight steam refined mineral oil and an extreme pressure lubricant consisting of the same oil but compounded with lead soap, is shown inFigure 5.

It will be noticed that at the prescribed test surface speed of 400 fpm of the Timken machine, the mineral oil carried 4600 psi, while the extreme pressure lubricant carried 28,000 psi, or more than six times the load, before scuffing or abrasion took place. The approximate load expressed in pounds per square inch is roughly 600 times the load in pounds on the lever arm of the Timken machine.

The legitimate use of extreme pressure lubricants is where the equipment is normally overloaded or subjected to occasional peak loads. They are not intended for gear drive where the load on the teeth is about 500 lb per inch of face or less, for example. On loads exceeding 1000 lb per inch of face they are mandatory.

The lubricant selected for the lubrication of the gears by means of sprays in a lubricating system is also satisfactory for the efficient lubrication of the adjacent bearing, whether of ball or roller type or babbitt lined sleeve type. This, obviously, is a further advantage in favor of extreme pressure lubricants since a lower viscosity oil may be used which will circulate freely and be suitable for both gears and bearings. There would thus be eliminated the difficulties of contamination if a heavy, viscous lubricant were used in the gear case and a light oil in the bearings.

Extreme Pressure Greases

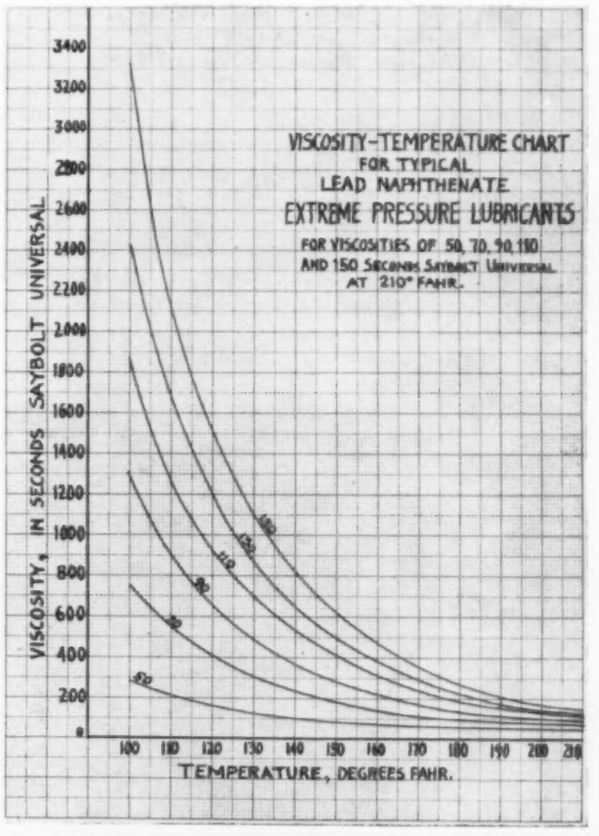
The foregoing referred largely to fluid extreme pressure lubricants which may be used in circulating systems and for splash lubrication, but the same principle also applies to non-fluid plastic greases for heavy duty application, such as the roller bearings in the work and back-up rolls of 4-high rolling mills and similar applications. For roll neck roller bearings, the preferred lubricant is a lime base grease employing a high viscosity oil and containing sufficient extreme pressure ingredients to result in a minimum O.K. load of 33 lb on the Timken machine. This formulation results in a grease that is water repellent and adhesive, with the necessary factor of safety to carry over peak loads.

In a heavy duty roll neck roller bearing, the pressures between the races and the individual rollers are enormous. A total pressure of 3,000,000 lb on one bearing is quite common in modern steel mill practice. The theoretical contact between the rollers and the hardened races is a line. Actually, due to the elasticity of the steel, it is a narrow area, with the rollers assuming a very slightly elliptical cross-section from the squeezing pressure. The race is also very slightly indented along the line of contact to conform to the cylindrical shape of the roller, and a slight ridge on the surface of the race occurs at either side of the roller. Figure 6 illustrates this condition in a highly exaggerated manner.

These deformations are all within the elastic limit range of the steel rollers and races and their original contours are recovered as the pressure is removed. The pressure on the bearings, however, is constant while the sheet is being reduced in thickness in rolling, and the deformation of the bearing elements continues in a wave-like motion, very similar to that observed when the wheel of a vehicle is rolled over an asphalt roadway in warm weather, or when a hand roller is passed over a rubber surface.

The elastic deformation of the bearing elements introduces fatigue stresses in the metal. Moreover, the slipping and sliding friction at the contact areas between the rollers and the cage retainers, produces power losses in the form of frictional heat. Correct lubrication re-

Figure 2 — Curves showing variation in viscosity with temperature for lead naphthenate lubricants.



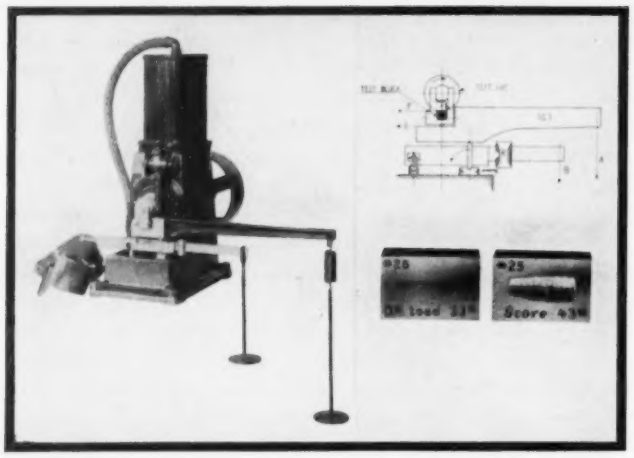


Figure 3 — The Timken lubricant testing machine is widely used to determine the efficacy of lubricants for industrial applications.

duces this friction, minimizes heating, and saves power. When a lubricant possessing extreme pressure properties is used on heavily loaded roller bearings, a safety factor is introduced and prevents failure of the bearing whenever an abnormal peak load arises. This momentary pressure is so high that the film of straight mineral oil or grease is ruptured and metal-to-metal contact occurs. Under these conditions of boundary line or partial lubrication, some scoring, and wear of the bearing elements take place. The scoring may be considered as due to actual welding or fusion of the microscopic steel surfaces in intimate contact under intense localized heat of friction. The fused particles are torn apart by the force of rotation, the highly finished surface of the rollers and races is ruined, and this condition is steadily aggravated until the bearing elements become so badly scored that the entire bearing has to be replaced. It is the function of an extreme pressure roller bearing lubricant to prevent the incipient stage of failure under conditions of abnormal load.

Lubricants for High Temperatures

Petroleum chemists succeeded in developing lubricants for extreme pressure conditions as far back as 15 years ago, and their present efforts are directed largely to further improvements. In the field of high temperature lubrication, however, the research laboratories succeeded in developing specialized products only very recently.

The palm of the hand is still our best thermometer — it is always with us and there is no mistake about its reading. If it is too hot to hold your hand against the bearing for a half a minute or so, it is a sign that something must be done to cool it off. Conventional lubricating oils and greases are adequate for normal operation where the heat of the bearing is due to mechanical conditions of speed and pressure. Bearings operating above 200 F are generally successfully lubricated with a high temperature grease of the soda base type.

In this paper we are concerned with bearings operated at considerably higher temperatures which are subjected to additional heat from external sources. Examples of such applications are the bearings in the mechanism operating the covers of soaking pits, conveyors adjacent to heating furnaces, and mill table bearings on plate and strip mills, where the steel may lie on the rollers five minutes or longer until it is passed through the shears to the cooling beds. This last example presents an acute lubricating problem now with the conversion of many strip mills to roll heavier plate. No temperature measurements are available, but it is estimated that such bearings frequently operate at temperatures in excess of 400 F.

Under such conditions conventional oils and greases deteriorate rapidly. Oils of high viscosity thin excessively and with volatilization of their lighter fractions they gradually become gummy from oxidation by contact with air, and finally solidify. A solid residue is left in

Figure 4 — Curve showing relation between film strength and viscosity for petroleum oils, as determined on Timken testing machine.

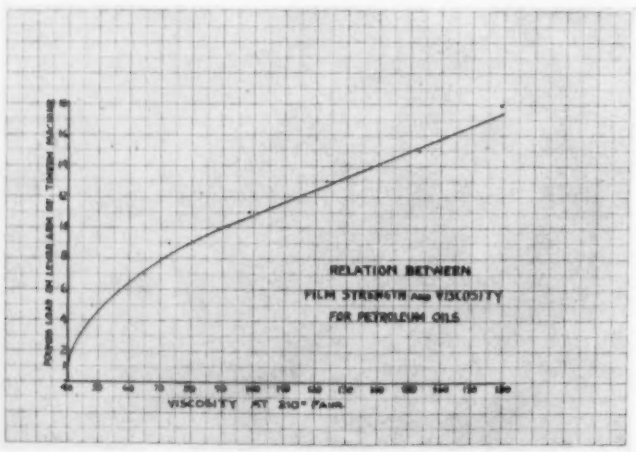
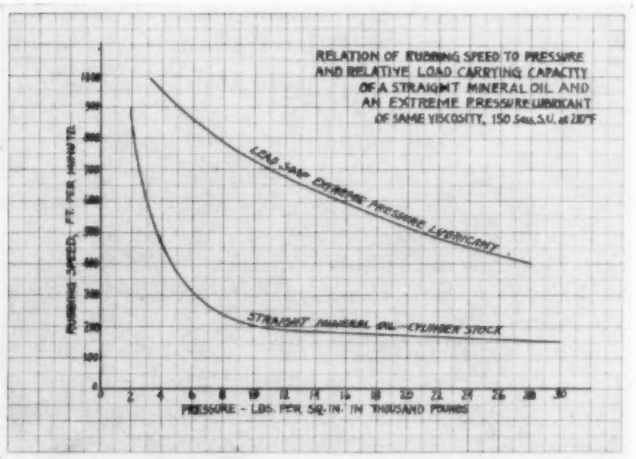


Figure 5 — Curves showing comparison of straight mineral oil and an extreme pressure lubricant of equal viscosity.


RELATION OF RUBBING SPEED TO PRESSURE
AND RELATIVE LOAD CARRYING CAPACITY
OF A STRAIGHT MINERAL OIL AND
AN EXTREME PRESSURE LUBRICANT
OF SAME VISCOSITY, 150 Saus. S.U. at 210°F
LOAD SAME EXTREME PRESSURE LUBRICANT
STRAIGHT MINERAL OIL - CYLINDER STOCK
RUBBING SPEED - FT. PER MINUTE
PRESSURE - LBS. PER SQ. IN. IN THOUSAND POUNDS

the bearings which fills up the oil grooves, increases friction, and begins to act as an abrasive. In the case of ball or roller bearings, the solid deposit sticks to the bearing elements, preventing free rotation, with the result that the races rub against stationary balls or rollers and the life of the bearing is shortened. Analyses of such solid deposits show that they consist largely of carbonized oil and gummy substances of an asphaltic or waxy nature.

Lime base greases are not suited for lubrication at temperatures much over 160 F, as there is a tendency in them for the soap to separate from the oil. Lime base greases contain a small percentage of water, which acts as a stabilizing agent between the soap and oil, and at the boiling point of water, 212 F, it evaporates. At temperatures lower than 212 F the rate of evaporation is slower, and it is only on bearings operated below 160 F that lime base greases may be used. At normal temperatures, say under 130 F, the tendency of lime base greases to break down due to the evaporation of the water which acts as a binder is practically negligible, as the bearing is usually replenished with fresh grease before any noticeable effect may be observed.

Properly compounded soda base greases may be used at temperatures up to about 300 F, with regular replenishing. Such greases do not contain water, and the soda soap is intimately admixed by dispersion with the oil. Soda base greases are preferable to heavy oils, because they do not liquefy, but at continued high temperatures of about 400 F they are subject to the same limitations as mineral oils; namely, volatilization, oxidation, and carbonization of their mineral oil content, which is aggravated by the presence of the soap. The selection of the proper grade of mineral oil in the manufacture of soda base grease improves its resistance to very high temperatures, but eventual accumulation of solid deposits which interfere with the operation of the bearing cannot be avoided.

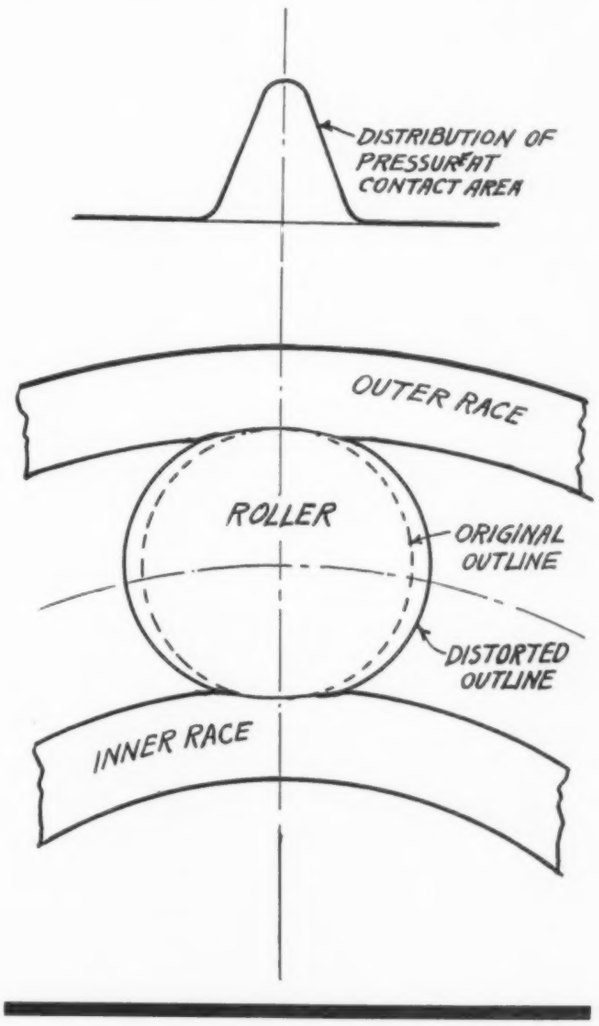
The latest development of the petroleum industry in high temperature lubrication consists in attacking the problem from a new angle. Since conventional oils and greases form objectionable deposits in bearings and are directly responsible for the failure of the bearings, why not discover a lubricant which is entirely free from ingredients which are converted into gummy and carbonaceous solid deposits at high temperatures? Instead of carbonizing, gumming up, and leaving an ash in the bearings why not make the lubricant disappear completely at a slow rate in the form of a gas? And if the new type of lubricant completely vanishes from the bearing in the course of, say, a few hours at the prevailing high temperature, is it not safer to replenish the lubricant at regular intervals than to ruin the bearing with a conventional lubricant which is converted into a harmful non-lubricant?

Mineral oil consists of carbon and hydrogen with a very small percentage of impurities in the form of sulphur, oxygen and nitrogen compounds. The hydrocarbon molecules in petroleum are of an infinite variety; some stable and others unstable; some light, other heavy, most of them desirable in lubricants and a few undesirable. Modern refining methods enable us to remove the undesirable constituents and to obtain a lubricating oil to accomplish a definite purpose. In the development of a lubricant for high temperature performance, the aim was to eliminate all low boiling hydrocarbons and impurities, so that there would be no deterioration of the lubricant below the temperatures where it would volatilize and disappear entirely rather than combine with oxygen and form a gummy mass which will eventually carbonize under continued heat.

Among the outstanding characteristics of the new type of high temperature lubricants the following may be enumerated:

1. *Gradual disappearance* without leaving solid deposits. At present these lubricants are available in four viscosities or consistencies, the lightest being a fluid oil of 50 sec Saybolt universal at 210 F, and the heaviest of a plastic consistency, with a viscosity of approximately 40,000 sec at 210 F. The flash points and initial boiling points of all four grades are close together but the rate at which they volatilize is different for each. The time intervals for the complete disappearance of these oils of representative viscosities are shown in Figure 7. This data was obtained in the laboratory by heating

Figure 6 — Sketch indicating the deformation of roller bearing under heavy load, and the pressure distribution over the contact area.



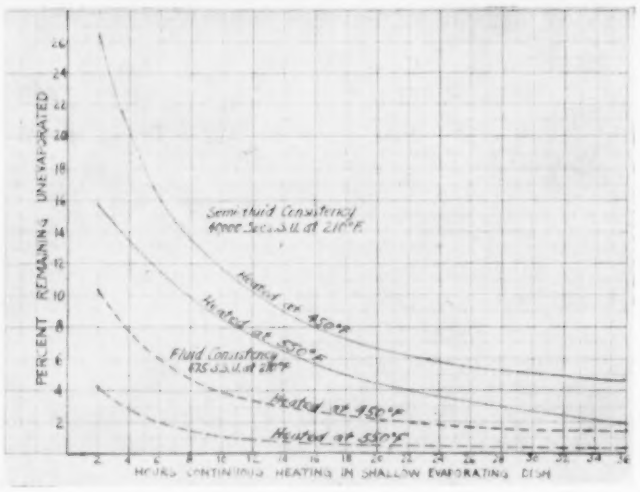


Figure 7 — These curves show the time required for disappearance of the new high temperature lubricants.

equal quantities of each lubricant at the temperatures shown and noting the amount left in the container at different time intervals, and this may serve as an indication of what might happen inside a bearing at corresponding temperatures. In general, a conventional mineral oil having a high flash point is not desirable for bearing lubrication at temperatures over 400 F, because it permits the oil to "crack" and combine with oxygen from the air to form gummy and solid deposits.

2. *Adhesiveness and cohesiveness.* The new oils, although of 100 per cent petroleum origin with no compounding nor additives, are of a stringy nature, indicating great internal cohesiveness and external adhesiveness to metallic surfaces. A lubricating film between the rubbing or rolling elements of a bearing is always present and resists being squeezed out under the bearing load. Two apparently contradictory requirements are thus met in these lubricants; first, the low volatility which permits gradual disappearance, and second, the marked cohesiveness which prevents the lubricant from spreading out, running off and going to waste before performing its function of lubrication.

3. *High viscosity index.* They are not affected in consistency with variations in temperature to the same extent as conventional mineral oils — with rise in temperature they thin but little and at low temperatures they congeal very much less. Figure 8 gives a comparison of the viscosity-temperature characteristics of three oils of the same viscosity of 150 sec at 210 F — two conventional mineral oils of 30 and 100 viscosity index respectively and a third one of the new high temperature type.

Figure 8 — Curves comparing viscosity temperature characteristics of new high temperature oil and conventional mineral oils.

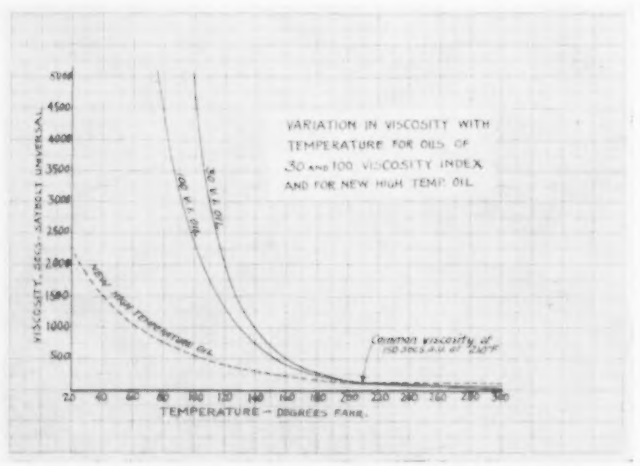

VISCOSITY, SECS. SAYBOLT UNIVERSAL
VARIATION IN VISCOSITY WITH TEMPERATURE FOR OILS OF 30 AND 100 VISCOSITY INDEX AND FOR NEW HIGH TEMP. OIL
30 V.I. OIL
100 V.I. OIL
NEW HIGH TEMPERATURE OIL
Common viscosity of 150 SUS at 210°F
TEMPERATURE — DEGREES FAHR.

Figure 9 shows what happens when equal quantities of a conventional mineral oil and the new lubricant are subjected to high temperatures. The conventional oil always leaves a brownish-dark solid deposit, while the new lubricant leaves no deposit. The two stainless steel discs shown in the photograph were heated to over 400 F. A few drops of a low viscosity, low carbon content conventional oil were placed on the disc at the right, and under the action of heat it thinned out, spread over the disc, decomposed or cracked, and left the hard, black deposit shown around the edge of the disc. The disc at the left was subjected to the same procedure, except that the new lubricant of a higher viscosity and in larger quantity was used. Ordinarily such changes in these two factors would make the type of test more severe. The lubricant did not thin out, but barely spread toward the disc circumference and disappeared completely. The black area at the top is the shadow from a shallow lip in the disc.

The disappearing property of the new oils is a time-temperature function, and the logical question is how often must the bearing lubricant be replenished. This depends on the viscosity and quantity of the oil used in the initial charge, the surface area to be lubricated, the time the oil is in contact with the surface, and the bearing temperature. Each application must be studied and the frequency of replenishing must be determined after a supervised test. The use of an automatic lubricating system, which feeds the lubricant to inaccessible points of application at regular time intervals and in a predetermined quantity is particularly advantageous with these lubricants, as it eliminates the human factor and results in eventual economy.

In some cases it is not possible to replenish the bearing with a fresh charge of lubricant as desired. To bridge over this gap, and to assure a measure of lubrication even after all of the lubricant has disappeared, these new high temperature lubricants are also available in grades containing colloidal graphite. The small percentage of graphite of colloidal size is dispersed throughout the lubricant, and serves the function of providing sufficient lubrication between the replenishing periods.

The following are some representative examples of the application of the high temperature lubricants in the steel industry.

1. Soaking pit cover mechanism.
2. Bearings on electric melting furnace, 300 to 1000 F bearing temperatures.
3. Bearings on revolving type shell heating furnaces.
4. Car furnace bearings for annealing armor plate.

Lubricant applied with pressure system before car is pulled in or out.

5. Armor plate forging presses, where the column guides are subjected to heat of radiation from steel at 2200 F.

6. Roll table bearings on a continuous strip mill, with plates or strip resting over the roller bearings. A recent supervised test on a mill table of a continuous strip mill showed that the bearings lubricated with the new high temperature lubricant for two weeks were in clean condition, and running free, while adjacent bearings lubricated with a conventional grease were gummy and filled with a coked deposit, and stopped revolving the moment the power was shut off.

In all of the above applications, conventional oils and greases failed to give satisfactory lubrication, and the accumulation of solid deposits in the bearings was a source of continual difficulty. The new high temperature lubricants solved the problem in each case.

These lubricants are designed as special products for application to bearings operated at temperatures of over 400 F, and they are not intended to replace conventional oils and greases at lower operating temperatures. The general rule of using the most economical and most available lubricant for any particular application should be observed in each case.

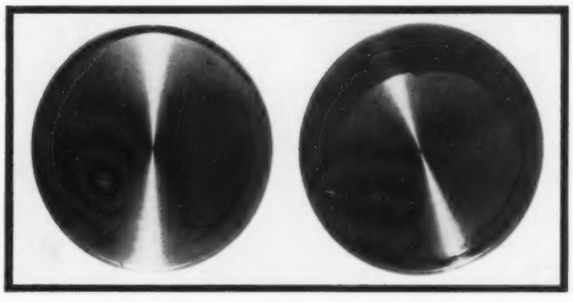


Figure 9 — High temperature oil dropped on a heated steel disc (left) disappears completely, while conventional oil leaves a hard black deposit (right).

Non-Staining Roll Oils

One usually does not associate high temperature lubrication with cold rolling, although the localized temperatures in the section of maximum flow of the metal are high. We are now dealing only with the desirability of non-staining properties of roll oils, and the utilization of the disappearing properties of the new high temperature lubricants as a means of accomplishing this purpose on certain types of cold rolling work.

In the cold rolling of strip and sheet metal lubrication is needed to minimize the friction between the flowing metal and the rolls at the arc of contact. Excessive lubrication is harmful, as slipping of the rolls will take place and the steady grip on the metal will be lost. In the rolling of tin plate at high speed, a combination of lubricant and coolant is necessary, so that the coolant may serve the purpose of controlling the contour of the rolls by thermal expansion and contraction.

In the finishing passes of thin gauge metal particular care must be exercised to use a roll oil having non-staining properties, and this is particularly true where a high surface finish is desired. The staining occurs during the finish anneal, even in annealing furnaces having atmosphere control. The heat of annealing does not vaporize the roll oil completely, and residual gummy and carbonaceous matter left on the metal causes stains. In high temperature bearing operation, this residual matter causes failure of the bearing, while in the annealing of finished rolled metal it causes indelible stains which mar the surface which may interfere with the further processing of the metal.

The causes of bearing failure and metal staining originating from the same source, it is obvious that the remedy for each may also be the same. The new types of lubricants described for high temperature bearing operation, therefore, also find application for critical rolling operation of steel, copper, brass, aluminum, and stainless steel. The principle involved is the same; namely, the complete disappearance of the roll oil at the annealing temperature without leaving any residue which may stain or etch the metal.

The requirements of a roll oil for bright finish is a balance between film strength for adequate lubrication to enable taking heavy reductions, and freedom from staining. The lubricants described are by their nature non-staining, and since roll oils are usually of a low viscosity, not exceeding 200 sec at 100 F, extra film strength may be imparted by the addition of certain oiliness agents which are known not to impair the non-staining properties. In this manner it becomes possible to take heavy reductions on the rolling mill and avoid the formation of stains during annealing.

Among the applications of these oils in cold rolling, mention may be made of the successful rolling of 18-12 stainless steel sheets, which are being annealed at 1900 F without preliminary removal of the roll oil. Copper and brass, as well as aluminum, are particularly susceptible to staining during annealing, and where a bright surface finish is specified, these oils will give the desire results and eliminate intermediate cleaning operations.

DISCUSSION

T. N. FRITSCH, Engineer, Homestead Steel Works, Carnegie-Illinois Steel Corporation, Munhall, Pennsylvania

M. RESWICK, Lubrication Engineer, Standard Oil Company of New Jersey, Pittsburgh, Pennsylvania

S. C. GRIFFITH, Lubrication Engineer, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania

S. J. SOROKA, Lubrication Engineer, Carnegie-Illinois Steel Corporation, Braddock, Pennsylvania

R. J. GRAHAM, Lubrication Engineer, Bethlehem Steel Company, Johnstown, Pennsylvania

(Continued on page 8)

K. W. ATWATER, Consulting Engineer, Pittsburgh, Pennsylvania

G. C. EHEMANN, General Foreman of Maintenance, Blooming Mills, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania

E. B. SVENSON, Metallurgist, Aluminum Company of America, New Kensington, Pennsylvania

M. C. MOCHEL, Design Engineer, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pennsylvania

T. N. FRITSCH: In regard to film strength, how do the high temperature oils discussed in the paper compare to mineral oils of like viscosity?

M. RESWICK: They compare more closely to a highly refined straight mineral oil. We must recognize the fact that an ordinary straight mineral oil contains some impurities which have not been removed in refining. A common black oil has probably more film strength than a well refined oil of the same viscosity.

S. C. GRIFFITH: Mr. Reswick mentioned EP lubricants as having a lead naphthenate base. Are not the sulphurized or chlorinated oils of the same nature? Is there a distinction between them?

M. RESWICK: There is a difference as regards composition, but not as regards load carrying capacity. One reason why lead naphthanates or lead soaps are preferable is because there is less tendency to corrosion than with lubricants containing chlorine and sulphur. I may add that for automotive purposes perhaps lubricants compounded with sulphur or chlorine are just as good as any other extreme pressure lubricants, because in an automobile you are supposed to change your oil in the differential at least twice a year, while in industrial gear drives you leave it in until the drive has to be repaired.

S. J. SOROKA: Is there any type of deposit left at all with this high temperature oil?

M. RESWICK: Under ordinary operating conditions where the temperature is in the range of 450 to 1000 F, evaporation is gradual and all of it will gradually disappear; but at temperatures over 1000 F the products of combustion may not be completely converted into H_2O and CO_2 and there may be a very small amount of residue in the form of a fine flake due to incomplete combustion.

R. J. GRAHAM: What resistance to water contamination do these products possess?

M. RESWICK: Lead oleates are susceptible to combination with water and form an emulsion which may be broken by the action of heat. Lead naphthenates are only slightly emulsifiable with water and if allowed to stand most of the water will settle out, and what is not settled may be eliminated by heating and allowing to stand for about ten hours.

R. J. GRAHAM: It is not as difficult as with oil?

M. RESWICK: If you refer to straight mineral oil, it must be realized that any oil, once it has been compounded with other materials, is not as resistant to water as the original oil. In other words, when you convert an oil into an extreme pressure lubricant by compounding with other ingredients you get from 5 to 7 times the original film strength, but you have to sacrifice something, such as lowered resistance to water; you cannot get something for nothing.

K. W. ATWATER: Mr. Reswick's paper shows his wide experience and that he has given the subject a great deal of study. Up until sixteen and twenty years ago, lubrication was no problem at all because nobody paid any attention to it. Up until that time, as far as steel mills are concerned nobody had gone into the many grades of composition of lubricants. We neither had combustion engineers nor lubrication engineers twenty years ago. In the operation of rolling mills at that time, if the roll necks became hot, the foreman of the mill or the roller would chuck a handful of tallow, grease or suet on the neck. Such applications of grease did very little or no lubricating at all; it accumulated all with mill dust and scale flying about the mill. Along that time the steel companies started to haves pecial engineers for the study of combustion and lubrication, and credit must be given to these lubrication engineers for a large part of the knowledge obtained in the lubrication of steel mill equipment. Before that time the manufacturers of lubricants had little knowledge of actual results obtained with oils and greases in operative use.

Since grease, tallow, etc., was inadequate, partly due to its form of application, the non-metallic bearing came into existence, where it was sufficient to merely cool the roll necks with water, and use only a little lubricant when the mill was idle. Also about 12 years ago steel mills were designed and built having much higher speeds; the anti-friction bearings for high speeds and heavy duty came into use. It was due to these combinations of factors, that the manufacturers of lubricants realized that these changing conditions and requirements had to be met. They worked hard and in conjunction with the lubrication engineer, and it is remarkable what has been done since that time, and I am one of those who appreciate what they have accomplished. We are now living in a period of emergency, where we all have to strive not only to conserve valuable metals but also valuable oils, and it is necessary to know which lubricants will give the longest life in maintaining metallic bearings, as another factor in our efforts towards victory.

G. C. EHEMANN: I have been wondering if this new high temperature lubricant wouldn't be a good thing to keep on hand for use in nursing a hot bearing along, instead of valve oil, sulphur, mica, etc.

M. RESWICK: High temperature lubricants are intended for application only where ordinary oils will not do their jobs, and usually where temperatures are above 400 F, because at lower temperatures their internal cohesiveness would result in a somewhat excessive internal friction. For nursing along or cooling off a bearing running hot due to misalignment or while the bearing is new and not broken-in, such practical expedients as sulphur, mica, graphite, etc., are preferable, as they have a tendency to wear down the rough spots and thus cause better seating of the journal in the bearing.

G. C. EHEMANN: I might mention a case of a rather peculiar failure of lubricant on a hoist worm drive on a crane. When a very heavy load was hoisted it frequently was held there and could not be lowered. This was a source of worry until the motor inspectors found that they could get out of trouble by laying a bar across some of the resistance banks in the dynamic lowering circuit. Investigation showed evidence of scuffing between the worm and the worm gear. The lubricant in this worm unit was changed to a lead oleate type EP lubricant, and so far we have not had a load stay up in the air since.

Another application of lubricant which was unusual: I saw the first gear failure primarily attributable to too good lubrication. On a reversing bloom table lubricated with cylinder stock oil the gears would wear out and were changed before failure could take place. This lubricant was changed to an extreme pressure lubricant. The gears then retained their tooth form so long that fatigue occurred at the root of the tooth, two teeth breaking out in service. That is a failure that was attributable to too good lubrication.

E. B. SVENSON: In substituting lead naphthenate grease for lead oleate grease in places where there was possibility of contamination with water, in several cases we ran into excessive foaming. Is that inherent in lead naphthenate?

M. RESWICK: It was probably the result of compounding certain oils with other oils which had not been highly refined. To eliminate foaming completely we must use a straight mineral oil. With an extreme pressure lubricant to overcome foaming it is necessary to have adequate settling and reduce the agitation. The tendency of mill designers to provide storage tanks of small capacity is primarily responsible for foaming. You should increase the size of your settling tank.

E. B. SVENSON: The tanks were satisfactory for lead oleate type of grease, as we did not have foaming within the tanks, but when we substituted lead naphthenate grease we ran into increased foaming.

M. RESWICK: Perhaps moisture got into the lubricant in some unsuspected manner and that may have been responsible for the foaming.

E. B. SVENSON: We do not necessarily have to expect excessive foaming with naphthenates?

M. RESWICK: The foaming tendency is less. Lead naphthenates do not hold as much water as lead oleates. I do not wish to leave the impression that lead oleates are no longer suitable for mill applications. In fact, a lead oleate lubricant will carry more pressure than one lead naphthenate base, but for most applications lead naphthenates have more than sufficient load carrying capacity.

S. J. SOROKA: If the amount of the high temperature oil at 600 F was reduced to 20 per cent of its original volume, would that be sufficient to produce scuffing?

M. RESWICK: The quantity of lubricant left after 36 hours in an evaporation test is still sufficient to provide an effective lubricating film until the next replenishing period.

M. G. MOCHEL: Industrial speed reducers are conservatively rated and in most instances tooth surface failure is the limiting factor and not mechanical strength. Do you see any objection to increasing the rating of industrial speed reducers by using an EP lubricant provided the stresses at the root of the gear teeth are not unreasonable?

M. RESWICK: I would not advise it because when you design a gear drive you design for mechanical strength. Increasing the power transmission rating by using a special lubricant will increase fatigue stresses and you will get results similar to what Mr. Ehemann mentioned in that there would be failure of the gear teeth through too good lubrication.

A. I. S. E. District Section Activities

Philadelphia, November 7th — "Plant Protection"

"Equipment," by Kinnard Pinder, E. I. DuPont de Nemours & Co., Wilmington, Delaware.

"Personnel," by Captain R. G. Gepzen, U. S. A., Philadelphia, Pa.

Pittsburgh, November 9th —

"Electric Fusion of Tinplate," by G. E. Stoltz, J. E. Hutcheson and R. M. Baker, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

"Machine Gas-Cutting of Alloy Plate," by S. D. Baumer, Air Reduction Sales Company, New York, N. Y.

Chicago, November 10th —

"Conservation of Materials in Steel Mill Maintenance," by L. A. Umansky, General Electric Company, Schenectady, N. Y.

Detroit, November 10th —

"War and Lubrication," by C. E. S. Eddie, lubrication engineer, Great Lakes Steel Corporation, Ecorse, Michigan.

Birmingham, November 30th —

"Change-over of the Plate Mill at T. C. I.," by R. R. Thomas, assistant chief engineer, Tennessee Coal, Iron & Railroad Company, Birmingham, Alabama.

C. H. WILLIAMS

GEORGE H. ROSE

L. A. WYND

NEW DISTRICT CHAIRMEN, A. I. S. E.

Walter H. Beyerle was born in Bernville, Pennsylvania and attended Perkiomen Seminary and Pennsylvania State College, receiving a degree in electrical engineering in 1909. He then entered the apprentice course at Westinghouse Electric and Manufacturing Company and after a year of training, was employed by the Pennsylvania Steel Company, at Steelton, Pennsylvania. He was then transferred to a subsidiary company, the Spanish-American Iron Company, at Felton, Oriente, Cuba. In 1912 he was employed as test engineer by the Pennsylvania Water and Power Company, and three years later became associated with Bethlehem Steel Company, where he served in the electrical construction and power departments in Bethlehem until his transfer to the Sparrows Point plant as assistant electrical superintendent.

F. C. Frye graduated from high school in Beaver, Pennsylvania, and started to work in engineering department of the Jones and Laughlin Steel Corporation, Alliquippa, Pennsylvania in 1912. He was transferred to the steam and fuel department in 1914, and in 1919 went to Heppenstall Forge and Knife Company in charge of boilers and fuel. Mr. Frye next entered the employ of Crucible Steel Corporation, Midland, Pennsylvania, as boiler superintendent, and in 1922 went with United Alloy Steel Corporation, Canton, Ohio, in charge of boilers and fuel at their South Division. In 1925 he entered the boiler and welding business in Beaver Falls, Pennsylvania. Two years later he became associated with Crucible Steel Corporation, Pittsburgh, Pennsylvania, and then with Wheeling Steel Corporation, Steubenville, Ohio. He became steam engineer for Great Lakes Steel Corporation in 1930, and in 1932 took charge of the fuel and steam departments.

F. B. Nielsen was born in Norway and graduated in mechanical engineering from Bergen Technical Institute in 1914. After serving in the Norwegian Army, Mr. Nielsen entered the engineering department of the Stavanger Electro Steel Works in 1916. He became plant engineer, in 1918, in charge of new construction and maintenance. During this time he was awarded a scholarship for the study of foreign steel plants. In 1922, Mr. Nielsen came to the United States, where he entered the employ of Inland Steel Company. He was then employed by the American Steel and Wire Company at Waukegan works, and in 1924 became associated with the Tennessee Coal, Iron and Railroad Company at Birmingham, Alabama.

George H. Rose, chief engineer of the American Steel and Wire Company, has been active in the engineering field for 40 years, 37 of which have been with American Steel and Wire. Following his graduation from Case School of Applied Science, in Cleveland, Mr. Rose served as a draftsman with the Cleveland Crane and Engineering Company from 1902 until 1903, when he became associated with Wellman-Seaver-Morgan Company. He also was employed with the Willard Storage Battery Company and the Jeffery Manufacturing Company of Columbus before joining American Steel and Wire. His first employment with the Wire Company was in 1905, when he began as a draftsman at the Newburgh Steel Works in Cleveland. He had been promoted to chief draftsman at Newburgh, before being transferred to Pittsburgh as an engineer in 1917. In 1922, he was appointed assistant construction engineer at Pittsburgh, and four years later was transferred back to Cleveland in the same capacity. The following year he became construction engineer of the Wire Company and in 1937 was appointed chief engineer.

Born in Wellsville, Ohio, Mr. Rose attended the township school and the high school at Wooster before matriculating at Case, from which he was graduated with a B.S. degree in mechanical engineering.

C. H. Williams was graduated from the University of Colorado in 1926 and was employed by Jones and Laughlin Steel Corporation as shear foreman in their Pittsburgh plant. In 1927 he became a junior engineer in the power department of National Tube Company at Pittsburgh, shifting in 1930 to the Ohio Works of Carnegie Steel Company. Here he served successively as junior engineer, power and fuel engineer, and assistant chief engineer. In 1940 Mr. Williams was transferred to the Pittsburgh office of Carnegie-Illinois Steel Corporation as power and fuel engineer on the staff of the chief engineer, and was subsequently appointed assistant chief engineer of the Pittsburgh district. In 1941 he was placed in charge of a newly organized defense engineering staff to coordinate the engineering of defense steel plant expansions of the company in the Pittsburgh district. He was subsequently transferred to the United States Steel Corporation of Delaware as assistant to the vice-president of engineering.

L. A. Wynd served an apprenticeship with the Illinois Electric Manufacturing Company, Peoria, Illinois, at the same time attending night school at Bradley Polytechnic Institute. Enlisting in the U. S. Navy in 1911, he attended the naval electrical school at Brooklyn, finishing his enlistment in 1915. For the next two years he served as electrical inspector on ship installations in the Brooklyn navyyard. Returning to Peoria in 1917, Mr. Wynd worked as electrical construction foreman on the Keystone Steel and Wire Company's new mill. He became chief electrician in 1918, and served in that capacity until 1935, when he went with Republic Steel Corporation as electrical superintendent for their Chicago district.

F. C. FRYE

W. H. BEYERLE

F. B. NIELSEN

Maintenance of BALL *and* ROLLER BEARINGS

. . . . proper maintenance and handling of ball and roller bearings in industrial repair shops call for a moderate amount of special equipment . . . .

By A. A. Van Pelt

Norma-Hoffman Bearings Corp.

PITTSBURGH, PENNA.

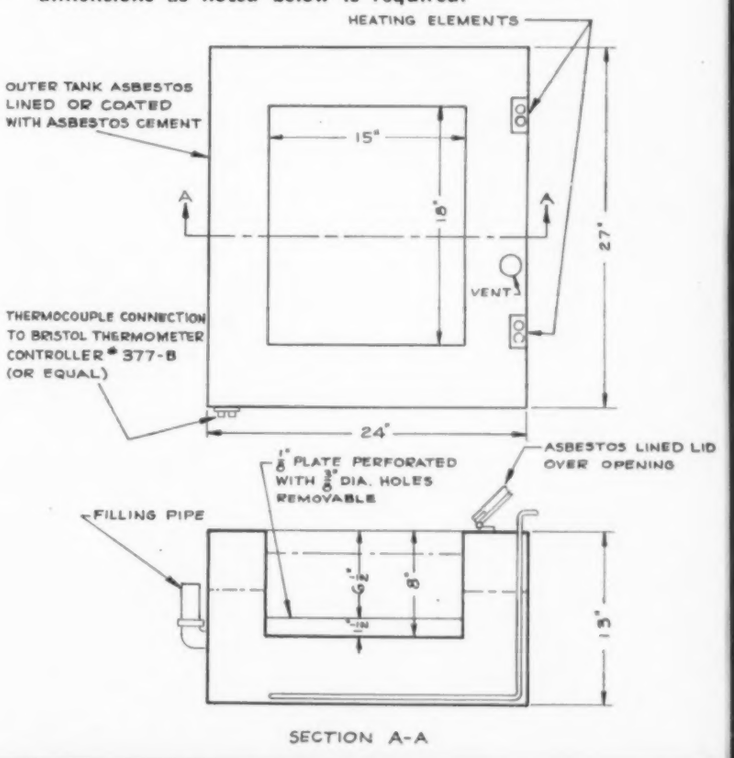
▲ THE proper and most effective methods of handling ball and roller bearings from a maintenance standpoint is a subject which apparently has not received sufficient attention in many of the electrical repair shops of large industrial plants such as steel mills, coal mines, glass factories, etc. While this subject should be of interest in normal, or even sub-normal times, for reasons of economy, under the present conditions when bearings are so hard to obtain due to war requirements and are being so overworked, it becomes a subject of paramount importance.

Due to the many varied types of bearing mountings in use today, it obviously would not be possible for this subject to be treated in complete detail, but it is the purpose of this article to cover the fundamental requirements for the proper handling of bearings in order to obtain their maximum useful life.

At the outset, let us consider the handling of new bearings. These should, of course, be stored in their original packages as received, for it is quite certain that all reputable bearing manufacturers are adequately slushing and properly wrapping and packing bearings to assure freedom from corrosion under anything but extraordinary conditions. It is not necessary to wash bearings as received from the manufacturer nor should the protective slushing compound be removed.

Let us now suppose a motor has come in for complete overhauling — new bearings, new (rebuilt) shaft, and new (or rebuilt) frame heads or end bells. Ordinarily the bearing seat on the shaft is machined in a lathe, and frequently a smooth finish is attempted with a file. Since it is almost impossible to maintain the necessary

Figure 1 — For heating the complete bearings or inner rings of roller bearings only, an oil pot of general dimensions as noted below is required.



tolerances or roundness of the shaft by these methods, we find that the interference fit between the bore of the bearing and the shaft is not what it should be. In many cases, after the motor is in service only a very short time, the inner race becomes loose which causes galling of the shaft and, of course, premature bearing failure results.

In an attempt to overcome this particular difficulty, many shops resort to a much heavier interference fit by making the shaft larger than the bearing manufacturers' recommendation. This procedure causes more trouble by expanding the inner ring to a point where the ring itself sometimes cracks, but more generally to a point where the balls or rollers are brinelled into the races. This, of course, causes heating and premature wear, but in addition the condition may be so severe that the outer race is forced to turn in the housing. This develops very severe heating and wear of the housing bore, so that in a short time complete bearing failure occurs.

The answer to all of these particular troubles is very simple. The use of a tool post grinder of the "Dumore" type gives a perfectly smooth bearing seat on the shaft and in the frame head, permits the proper tolerances to be more readily obtained, assures that the surfaces are more nearly round than with a file finish, and gives the correct fits for maximum bearing life.

Let us assume now that the bearing fits for both the bore and the O.D. of the bearing have been properly made as outlined above, and that all bores are concentric and parallel with the shaft. The next step is to mount one of those new bearings which we have on the shelf (it is assumed in this case that new bearings are required).

Many shops still drive the bearings onto the shaft. If carefully and properly done the results in general are fairly satisfactory. However, so frequently this procedure results in the bearing being cocked on the shaft, thus causing early failure. A still better method is to press the bearings on by using a good arbor press. However, this procedure requires extra effort and setup time and a press is not always available.

Heating the bearing to a correct temperature and simply pushing it onto the shaft seems to be the easiest and quickest way to handle the job. During cooling the bearing should be held against the shoulder on the shaft or after the bearings have cooled down sufficiently they may be driven against their shaft shoulders by means of a piece of pipe or tubing to assure that they are properly seated. At this stage of the mounting procedure driving against the inner race through the pipe has no tendency whatever to cock the race or tear off tiny particles of metal ahead of the bearing.

A number of excellent methods of heating the bearings properly are available. In the smaller shops where the maximum O.D. of the bearings does not exceed a matter of 6 inches to 8 inches or so, the ordinary electric kitchen "turkey" roaster will do an excellent job if the temperature is not allowed to exceed 250 F. The only trouble with these units is that generally a log chain is required to keep them where they can readily be found.

Where numerous bearings are being mounted, an electrically heated oil pot will be found more advantageous. Figure 1 indicates a general arrangement with

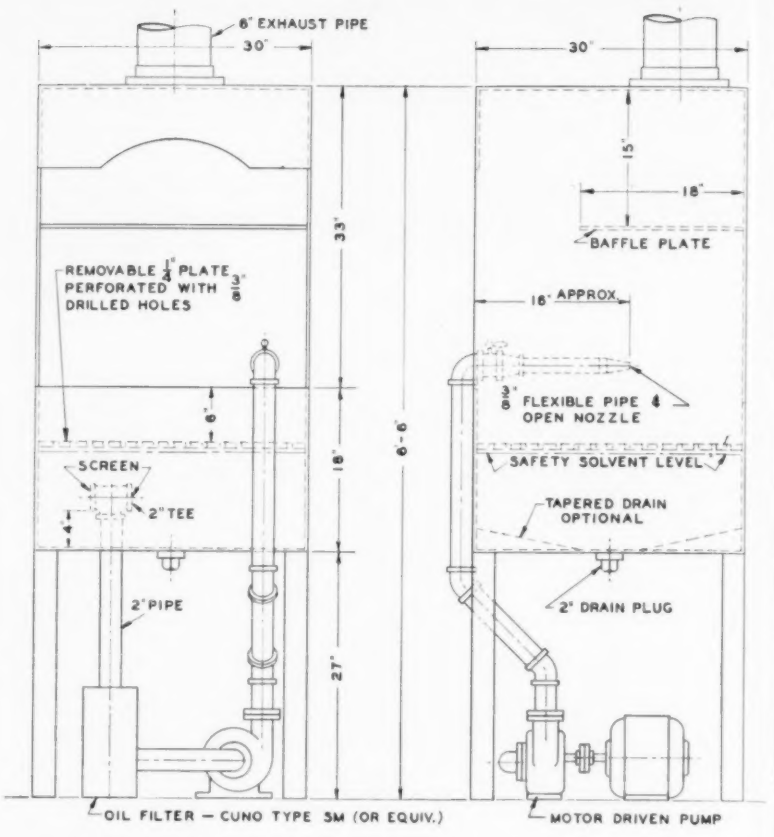
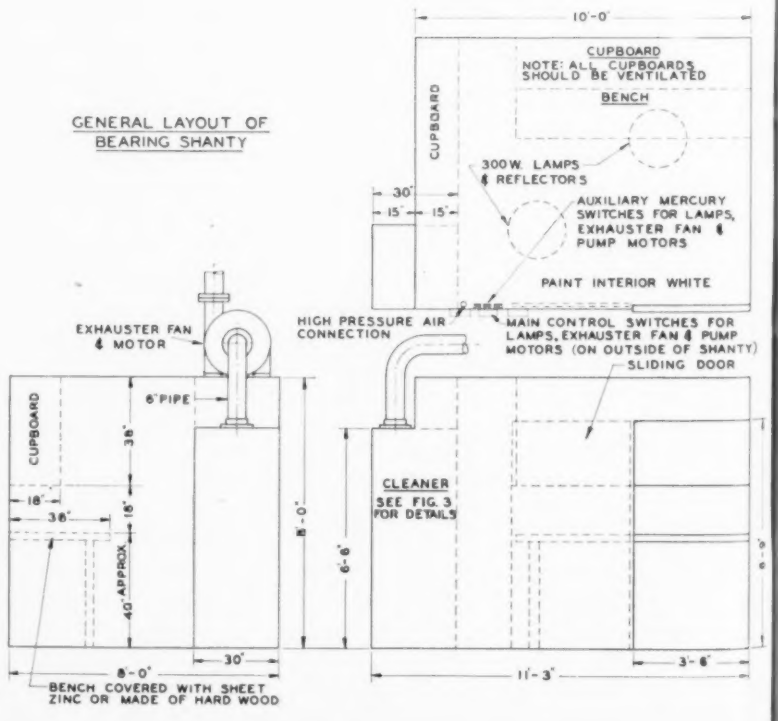


Figure 2 — The heart of this arrangement is the cleaner for which general dimensions are shown above.

▲

Figure 3 — General layout of the bearing shanty which includes the cleaner and ample storage space for bearings, lubricants and measuring instruments.



certain dimensions which will help the average shop to build their own oil pot and control panel.

It should be noted here that when dry bearings are heated in the roaster noted above, or in any hot air oven, they must be heated somewhat higher than when using an oil bath and they should be rushed to the shaft immediately after removal from the oven as the dissipation of heat is quite rapid. On the other hand, when the bearing is heated in the oil pot, it retains its heat (and therefore its expanded condition) somewhat longer due to the protective film of hot oil which covers it completely.

While we are on the subject of heating bearings, it may be well to consider those motors such as mine locomotive motors, and some types of end bells used on certain heavy duty motors, in which the inner end cap or bearing seal is an integral part of the frame head or end bell. This presents a rather difficult assembly problem. In the large majority of shops handling these particular units, the usual procedure is to place the frame head over the shaft, mount the inner race on the shaft, and then lace the outer race into the housing and over the rollers, at the same time. This is not so bad with roller bearings of a smaller size, but when large sizes are involved the result is generally that, because of slight out-of-alignment of parts, generous gouge marks are cut into the outer race when it is finally driven or forced into position. When ball bearings are being mounted in such a unit the job is still more difficult. The bearing itself is a complete unit and cannot be heated as the O.D. would be entirely too large to fit into the housing. Therefore, the usual method of handling such a job in the average shop is to try to drive the bearing onto the shaft and into the housing at the same time without peening the balls into the races. Due to the fact that this peening occurs in a large percentage of cases, the life of many ball bearings is materially reduced because of this particular assembly operation.

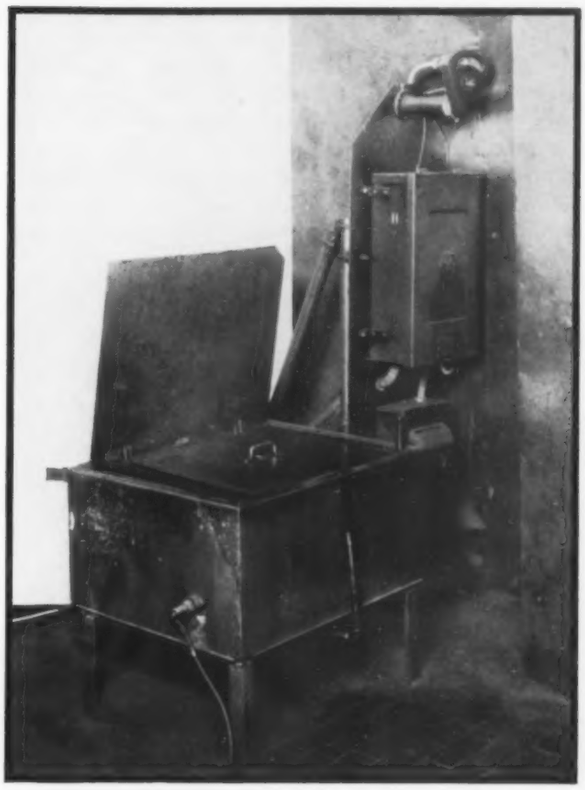


Figure 5 — The temperature of the oil in the oil pot should be carefully controlled by the necessary instruments mounted on a convenient panel.

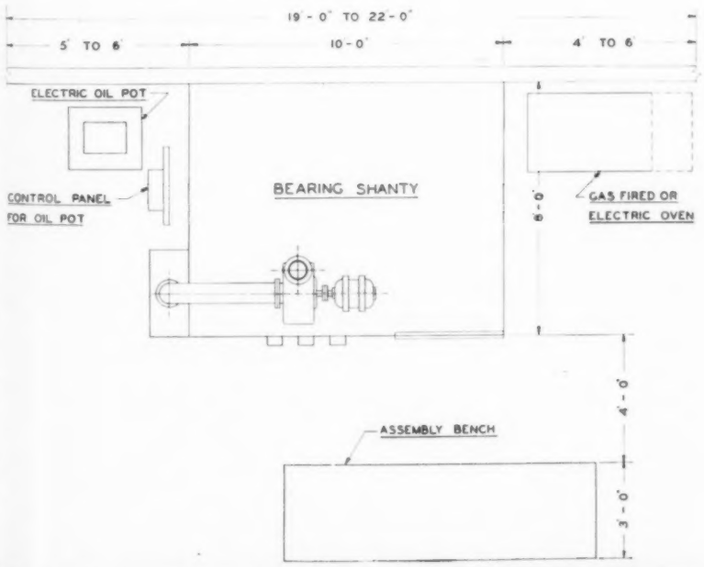
Here again there is a very simple — and money saving way in the end — to handle the problem. The entire bearing should be placed into the frame head or end bell and then the combined unit should be heated to the proper temperature, so that without removing the bearing, the complete unit can be pushed onto the shaft to its proper position. After it has cooled sufficiently the inner race of the bearing is given a few blows through a piece of proper sized pipe to be sure that it is properly seated against its shoulder.

The heating oven in this case can either be a gas fired affair built right in the shop or one of the electrically heated coil preheating ovens which can be purchased complete from the various electrical equipment manufacturers. The temperature control on such electric units is, in general, more satisfactory and there is also much less variation in the actual temperature between the top and bottom of the oven.

By the use of an oil pot (or turkey roaster) for the bearings only, and the heating oven (electrical or gas fired) it is possible to take care of the entire problem of properly mounting either ball or roller bearings on the shafts and in practically any kind of housing.

So far we have only considered the application of a new bearing. However, we must also consider those bearings which have been in service for some time and which are still in usable condition or where we must find out if they are still usable. Normally, the bearings

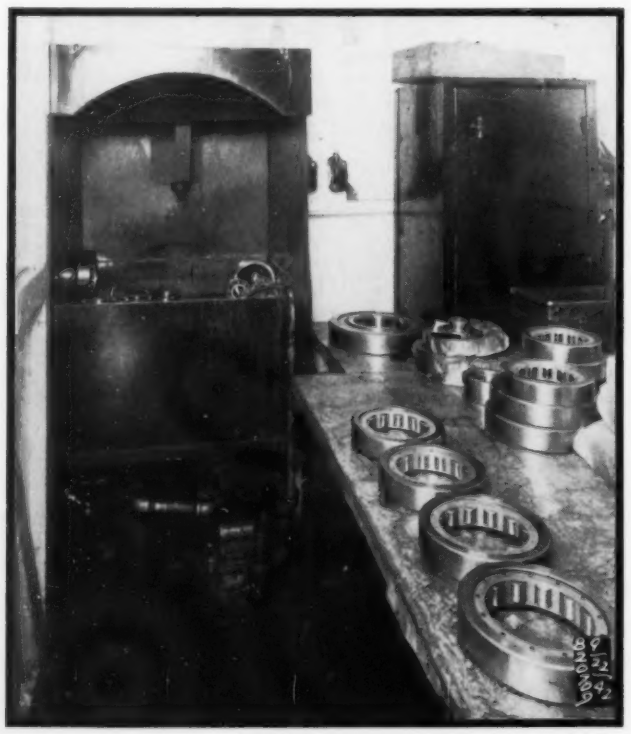
Figure 4 — Suggested plan layout of bearing shanty, oil pot and heating oven, etc.



which are removed from a shaft should only need washing thoroughly in some non-corrosive solvent. Unfortunately, however, there is a super-abundance of cases where poor grease has been used, where there has been insufficient grease, where the grease has broken down due to excessive heat or where dirt or grit or coal dust has worked into the housing, with the result that the bearing is all caked up with either a hard, gritty, or gummy deposit, or covered with a charred residue which cannot be removed by ordinary means. If these bearings could be thoroughly cleaned and properly lubricated they might be good for many days of additional life in the majority of cases. However, in too many instances the usual procedure in trying to clean these bearings is to wash them (even using a brush of some kind) in a bucket of something which at one time was gasoline. When bearings so handled are put back into service it is only a matter of a short time until complete failure occurs because it is impossible to remove all of the gritty or gummy foreign matter from around the retainers and balls or rollers by this method.

To properly take care of such bearings, and also to provide a central storage location, it is suggested that a bearing shanty be built somewhere in the repair shop. The size of this shanty should be about 8 x 10 x 8 feet high. In one corner of the shanty should be located the "cleaner" which unit is obviously the heart of the arrangement. It should consist of enclosing walls having an opening in front through which the dirty bearings are handled. Just below the perforated plate on which the bearings are supported is a reservoir to hold the cleaning solvent. Proper connections are made from this reservoir or tank to a suitable filter, such as the Cuno Type-SM, from which a small centrifugal pump delivers the solvent through a flexible pipe to a nozzle. When the pump is running, the solvent flows through the nozzle continuously under considerable pressure which generally is sufficient to thoroughly clean all of the refuse and debris out of the bearing.

Figure 6 — The cleaner is mounted in one corner of the bearing shanty with the necessary filter, pump, and motor located beneath.



However, there are sufficient cases where the muck and caked grease sticks tight enough to the bearing to warrant the installation of a high pressure air line, with the necessary rubber hose and pressure nozzle. This air nozzle is used alternately with the solvent and even then sometimes it is impossible to remove all of the muck at once. In these cases the bearing is placed upright in the back of the cleaner and the solvent, under pressure, is played on the bearing long enough to soften the caked grease. This can be done by laying the nozzle on a block of wood, leaving the operator free for other duties.

The suggestion that high pressure air be used on the bearings as noted above, should not be construed as a general recommendation to clean bearings with air. In practically all cases the air is contaminated by various quantities of water, which in the ordinary method of use will cause rust, and this, of course, is very undesirable. However, in the procedure here described the almost simultaneous use of the solvent under pressure with the air (even though it is damp) assures the immediate removal of the water bubbles to be replaced by the solvent. In many years of use of such an arrangement there have been no instances of any rust developing on the bearings after proper treatment.

The top section of the cleaner should be enclosed, except for the opening at the front as mentioned previously. As undesirable fumes are developed from practically all of the solvents that may be used, it is very necessary to ventilate the "cleaner." An exhauster fan mounted on top of the shanty and connected to the "cleaner" by means of a 6 inch diameter pipe takes care of removing the fumes which are liberated.

While main switches for the motors driving the pump and the fan are mounted on the outside of the shanty, it is very convenient to have auxiliary switches, of the mercury type (to eliminate any possibility of sparks igniting the solvent fumes) mounted right along-side of the "cleaner." Similar switches should also be used for the lights.

After the bearings are thoroughly cleaned, they should be allowed to drain for a while and then coated with vaseline or petrolatum jelly, if they are to be used within a short period of time. However, if they are to be stored for any appreciable time it would be advisable to use a slushing compound. A good compound is made by heating a mixture of 75 per cent petrolatum with 25 per cent of medium bodied neutral oil to 170 F and immersing the bearings therein until they reach the temperature of the bath. The bearings, after slushing or coating, should be wrapped in oil-resistant glassine paper of neutral quality.

There may be instances where facilities or equipment are limited, or where the volume of bearings cleaned does not warrant the above complete layout. In such cases the recommended procedure for cleaning bearings as adopted by the Annular Bearing Engineers Committee (A. B. E. C.) is of particular interest as it is based upon the combined experience of the various

manufacturers of anti-friction bearings. We are indebted to this committee for their recommendations which are as follows:

"1. *Cleaning Unmounted Bearings Which Have Been In Service*

"Place bearings in a basket and suspend the basket in a suitable container of clean cold petroleum solvent or kerosene and allow to soak, preferably over night. In cases of badly oxidized grease, it may be found expedient to soak bearings in hot light oil (200 to 240 F), agitating the basket of bearings slowly through the oil from time to time, or in extreme cases boiling in emulsible cleaners diluted with water, will usually soften the contaminating sludge. If the hot emulsion solutions are used, the bearings should be drained and spun individually until the water has completely evaporated. The bearings should be immediately washed in a second container of clean petroleum solvent or kerosene and immediately clean each bearing individually by revolving by hand with the bearing partly submerged in the solvent, turning slowly at first and working with a brush if necessary to dislodge chips or solid particles before finally spinning the bearing freely. The bearings may be judged for their condition by rotating by hand. After the bearings have been judged clean, they should immediately be spun in light oil to completely remove the solvent, coated by hand with petrolatum if they are not to be reassembled immediately and wrapped at once in clean oilproof paper while awaiting reassembly.

"The use of chlorinated solvents of any kind is not recommended in bearing cleaning operations because of the rust hazard involved, nor is the use of compressed air found desirable in bearing cleaning operations.

"2. *Cleaning of Bearings as Assembled in an Installation*

"For cleaning bearings without dismounting, hot light oil at 180 to 200 F may be flushed through the housing while the shaft or spindle is slowly rotated. In cases of badly oxidized grease and oil, hot aqueous emulsions may be run into the housings, preferably while rotating the bearings until the bearing is satisfactorily cleaned. The solution must then be drained thoroughly, providing rotation if possible, and the bearing and housing flushed with hot light oil and again drained before adding new lubricant. In some very difficult cases an intermediate flushing with a mixture of alcohol and light mineral solvent after the emulsion treatment may be useful.

"If the bearing is to be relubricated with grease, some of the fresh grease may be forced through the bearing to purge any remaining contamination. This practice cannot be used unless there are drain plugs which can be removed so that the old grease may be forced out. Also, bearings should be operated for at least twenty minutes before drain plugs are replaced as excess lubricant will cause serious overheating of the bearing.

"3. *Oils Used for Cleaning*

"Light transformer oils, spindle oils or automotive flushing oils are suitable for cleaning bearings, but anything heavier than light motor (S. A. E. 10) is not recommended. An emulsifying solution made with grinding, cutting or floor cleaning compounds, etc., in hot water, has been found effective. Petroleum solvents must be used with the usual precautions associated with fire hazards."

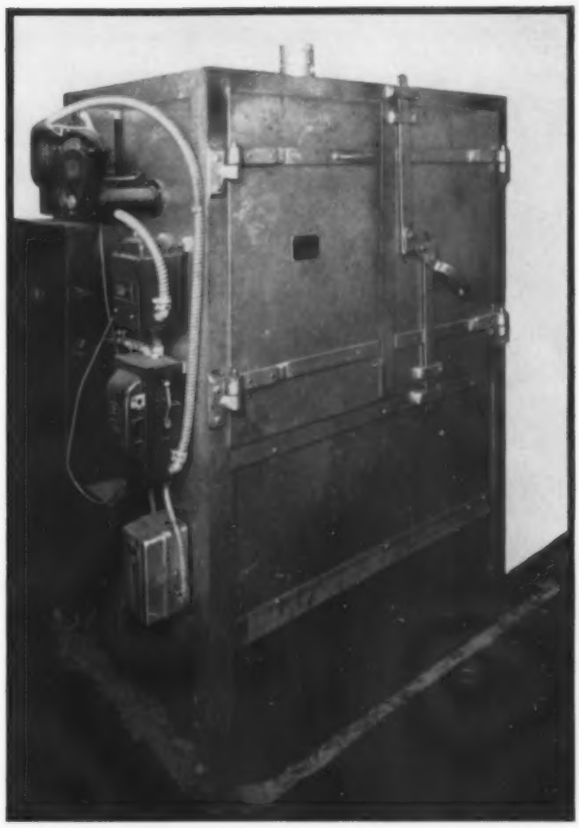
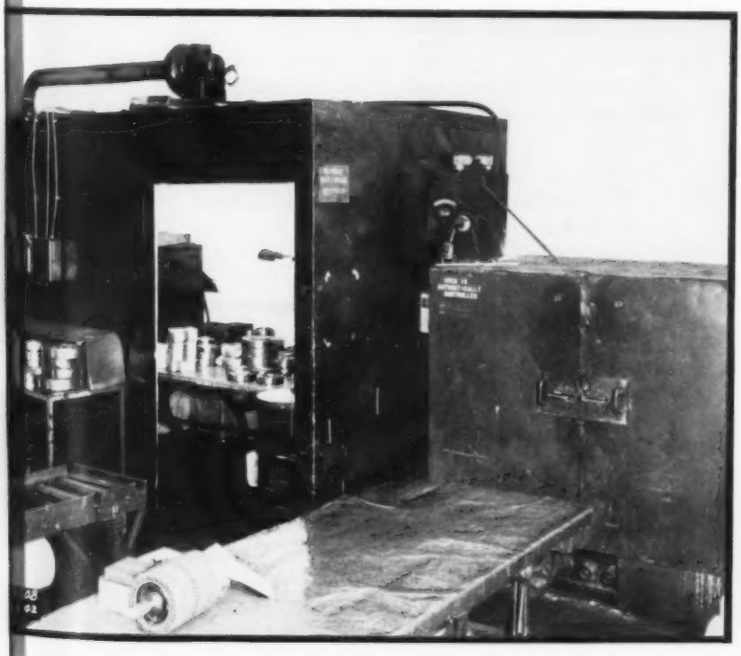


Figure 8 — Type of electric coil pre-heating furnace adaptable for heating end bells and frame heads complete.

Figure 7 — Compact arrangement of bearing shanty heating oven, and assembly bench with oil pot (not shown) located at rear of shanty.



ALLOY STEEL CLADDING
and Pressure Vessels

. . . . clad or composite steels are practical, save valuable metal, have high heat conductivity, and will take deep drawing readily . . . their use is expected to expand . . . .

By H. S. Blumberg, METALLURGIST

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Presented before A. I. S. E. PHILADELPHIA SECTION

▲ RAPID progress has been made in the steel industry with the development and continually increasing use of one of the newer types of material, as a result of which there has been available to the metal user for the past decade and longer bi-metal combinations with varying degrees of bonded strength between various compositions. These combinations are termed among other special names composite metals, clad metals, or lined metals, and they are produced by several processes with different metals.

Because of limited time available this paper will be confined to the ferrous group of bi-metals. It appears that the bi-metal products which do not contain steel in at least one part have not been as thoroughly exploited in massive form as the ferrous group. However, completely non-ferrous composites are available but a discussion of these should form the basis of another paper.

The majority of ferrous bi-metal composites function today mainly in services where corrosion resistance is required. However, composite steels are also available in which advantage is taken of the extreme hardness of certain compositions to produce cutting tools, but progress along this line has not been sufficient to threaten as yet the single compositioned tool steels. It may also be stated that an increasing amount of armor plate of the non-homogeneous type is being used, and such material is also classified as clad or composite steel.

This discussion will refer entirely to the steel composites in which it is desired to obtain corrosion resistance at limited cost.

A simple analysis will show why the composite type of material has resulted:

1. Certain metals which possess a number of unusual and desirable characteristics are generally relatively expensive.
2. Certain non-metallic materials also possess special qualities but may lack sufficiently in other necessary characteristics, such as, strength, ductility, and shock resistance.
3. Both these types of materials are practically completely inert to certain environments.
4. When materials are practically immune to corrosion media, the user usually takes advantage only of the desired metal property at its surface.
5. It is, therefore, of economic advantage to produce a bonded combination of materials which consists of a thin layer or layers of materials of specially desired properties and of less expensive massive backing material of sufficient strength, such as plain carbon or low alloy steel.

The term "clad material" should be defined. From a broad viewpoint, clad material involves a combination of two or more materials in which particular advantage is taken of the special characteristics of at least one of the compositions. Automatically, this definition would seem to include electroplated metals as well as metal sprayed materials. However, experience up to the present time has shown that where a layer of very slight thickness has been produced, imperfections in the protecting surface have been found. It is on this basis that one author has defined the material under discussion as having at least three per cent of the total thickness consisting of the special surface material. This figure is

purely arbitrary and will undoubtedly be changed in the light of future experience.

It may be well to point out here that the term "clad material" should perhaps be reserved for those combinations in which the special material is present at the surface, whereas the term "composite steel" has a broader significance and should possibly refer to the clad materials as well as those combinations in which the special materials are present internally, in products such as jail barstock, vault doors and the like. Because by far the largest part of composite steels used today have a surface layer selected to withstand corrosion, the term "clad steel" has come to be associated with corrosion resistance.

The majority of the special materials used at present to coat steel for corrosion resistance are metallic. However, a few non-metallic surfacing compositions are used today. The combination of non-metallic surface and metallic base are not here included under the classifications of clad and composite steels, but they are mentioned since they are also used for corrosive conditions but at relatively low temperature and pressure. It will be generally agreed, however, that in a composite for pressure vessel service at least one of the materials should be a metal in order that the structure will have strength, ductility, and shock resistance.

In the majority of products available today the backing material consists of plain carbon steel. However, carbon molybdenum steel is being used more frequently. For the purpose of centering this discussion, it will be limited, therefore, to those combinations in which plain carbon or carbon molybdenum is the base material, in which case one deals with clad steel. From this viewpoint, then, the variable with respect to composition becomes the protective or special property material.

Metals with Non-Metallic Linings

Such metal combinations are relatively few in number. The speaker knows of only two types of compositions used for the surface, certain silicates such as concrete, and the highly elastic materials, rubber or neoprene. These materials do not bond nearly as well with steel base metal as do the corrosion resistant steels. Both these materials are applied to a pressure vessel after the latter has been completely formed. In spite of limitations, both of these linings have been successfully used for certain restricted services where the operating conditions are primarily limited to special corrosive conditions to which these two compositions are practically immune. Some vessels are now operating in the petroleum industry where the lining is concrete. However, few such vessels are now being fabricated.

Metallic Clad Steels

The history of metallic clads represents a considerable longer period of time than the recent period of more practical developments. A review of the patent literature will show that some fifty years ago it was attempted to produce these combinations by pouring one metal on top of another or alongside. The difficulties in producing satisfactory composites seem to have been due to lack of temperature control at the joint where it is necessary for the two compositions to knit together. As a result, it may be said that for thirty-five years of the period mentioned, no thoroughly satisfactory material was evolved.

It is only within the past ten or fifteen years that satisfactory massive clad materials have been available. These compositions will now be discussed.

Present Day Metallic Clads

These metallic clads may be considered as follows:

A. The surface cladding metals and their individual properties.

B. The backing materials.

C. The processes used for producing clad steels.

A. *The cladding metals used and their individual properties.*

The cladding metals most commonly used today are as follows:

1. Plain chromium steels of low carbon content in the range of 11 to 27% chromium.
   - Type 410 — low C, 12% Cr
   - Type 430 — low C, 17% Cr
   - Type 446 — low C, 27% Cr
2. High chromium nickel steels, with and without columbium or molybdenum.
   - Type 304 — low C, 18% Cr, 8% Ni
   - Type 347 — as above plus columbium
   - Type 316 — 18-8 with 2½% Mo
   - Type 317 — 18-8 with 3½% Mo
   - Type 310 — 25% Cr, 20% Ni
3. Non-ferrous materials.
   - Pure nickel
   - Monel
   - Inconel
   - Copper

A-1. These steels are particularly resistant to the corrosive effects of sulphur at elevated temperatures. Accordingly these compositions are particularly well adapted to petroleum refinery service when sulphur is present at elevated temperature. Type 410 steel is the most common type of this group used in the refinery since it appears to contain sufficient alloying element to satisfy most conditions. However, in general as the severity of corrosion increases, higher chromium is needed in the metal. Types 430 and 446 are also used in the chemical industry. Of the three types in this group only type 410 responds fully to heat treatment since the higher chromium steels with low carbon content have no critical points. Accordingly it is not easy to refine the grain in the alloy portion of all clad steels. Type 410 is an air-hardening steel, hence it must be carefully heat treated to restore ductility after hot working and welding. Types 430 and 446 do not become hard after rapid cooling from high temperature, but it is still desirable to "anneal" these steels, since, even at best their ductility is not as good as the lower chromium steel. These steels are hot rolled without too much difficulty and they have nearly the same coefficient of expansion as plain carbon steel. These chromium steels are weldable but the ductility of the welded joint decreases markedly as the chromium increases beyond 16 per cent.

Type 410 is the least expensive of the so-called stainless group of steels. All these compositions have considerably better oxidation resistance than plain carbon steel, this property increasing as chromium content is raised. None of these steels have any better creep strength than plain carbon steel, hence they are used only for their corrosion resistant qualities.

A-2. The austenitic chromium nickel steels are the best known and the most commonly used of the corrosion resistant steels in the United States. These steels have not only considerably superior corrosion resistance to the plain high chromium steels but better high temperature strength as well. One disadvantage in using this type of metal is high cost. In practically all cases, however, where the chromium nickel steels are intelligently selected, there is no alternative because the lower cost steels do not possess the necessary corrosion resistance or high temperature strength.

These steels are rolled with more difficulty than plain carbon steels and are subject to more defects which require more frequent conditioning in the mills. Type 304 is the simplest analysis of this group for the mill to manufacture. The addition of columbium makes the steel somewhat more difficult to handle. Molybdenum austenitic steels are extremely stiff, even at high temperatures, and give the mill considerable trouble. Type 310, 25% Cr — 20% Ni, is nearly equally difficult to manufacture, with the result that each mill has worked out extremely carefully detailed procedures for the handling of these high alloy steels which must be rigidly adhered to, in order to keep rejections to a minimum.

Type 304 is the most commonly used steel of this group. It is, however, sensitive to excessive carbon above a very small amount, in that if this carbon is not dissolved in the steel, carbides will precipitate at the grain boundaries with possible resultant inter-granular corrosion. The carbides are precipitated in the temperature range 900F to 1600F. Thus if corrosive service is extremely severe, carbon should be put in solution by heat treatment consisting of heating to 1800F or higher, holding for sufficient time to dissolve the carbon and then by cooling rapidly enough to keep the carbides in solution.

Where welding is employed, and corrosive service is severe in the temperature range 900F to 1600F, obviously previous solution heat treatment is not helpful, since carbides will be precipitated in service with possible early failure. Fortunately columbium or titanium bearing steels are available in which a relatively small percentage of either provides an element for which the carbon has a greater affinity than for chromium. Thus columbium or titanium carbide is precipitated in preference to chromium carbide, and the important element, chromium, is kept in solution without resultant possible intergranular corrosion. Type 347 (or type 321, Ti bearing) is thus indicated for severe service where welding is used, where high temperature heat treatment cannot be carried out or where service temperature is in the carbide precipitation range, 900F to 1600F.

The molybdenum bearing steels (types 316 and 317) are selected for certain special types of corrosive service where types 304 and 347 are not quite satisfactory. The paper industry is a common user of these alloy steels. Pitting is prevented by the addition of molybdenum. Type 310 alloy is not frequently used because of its high cost. This steel has unusual corrosion resistance and extremely high oxidation resistance.

All of the alloy steels of this group have a coefficient of expansion approximately 50 per cent greater than plain carbon steel and a conductivity about one-half to one-third of that of ordinary steel. These austenitic steels are not difficult to weld.

A-3. The non-ferrous metals are coming into increasing use as part of clad steels. Such surface materials are selected for their particular resistance to corrosion. These composite steels are weldable by the use of proper technique.

B. Little need be said regarding the backing materials used in clad or composite steels. The common backing metal is plain carbon steel, although carbon molybdenum steel, because of its greater strength at high temperature is being specified more frequently. Both of

TABLE I

Types of Steels Used Today for Making Clad Steels for Corrosion Resistant Service

As facing materials	As backing materials
Type 410 — 12% Cr	Plain carbon steels
Type 430 — 17% Cr	Carbon-molybdenum steels
Type 446, Low C — 27% Cr	
Type 304 — 18% Cr, 8% Ni	
Type 347 — 18% Cr, 8% Ni, Cb	
Type 317/ — 18% Cr, 8% Ni, Mo Type 316/	
Type 310 — 25% Cr, 20% Ni	
Pure Nickel	
Monel	
Inconel	
Copper	

TABLE II

Clad Steels with Reference to Method of Manufacture

	Integral	Partially bonded
	Casting method	
Ingot or slab and special material are joined and then hot rolled to final dimensions.	Assembly method — a. b. c. d.	
	Fusion intermelting — a. b. c.	
Alloy sheet joined to base metal plate — no subsequent hot mechanical working.	Continuous resistance welding method	Plug welding method
		Spaced resistance welding method
		Strip welding method

these metals are so well known that no further discussion will be given here.

C. *The processes used for producing clad steels.* Table II classifies the methods which are used to manufacture clad or composite steels. In this classification the processes are broken down with respect to whether the composte material is hot rolled to final dimensions after the metals are joined or whether the method involves an alloy sheet joined to the base metal plate without subsequent hot mechanical working. Further classification is given in terms of whether the finished product is integral or partially bonded. The term integral is defined to mean that the contiguous surfaces of facing and backing materials are entirely bonded to each other; the degree of bonding depends on the method used in the manufacture of clad steels, since all products on the market do not have equal bond strengths. Partially bonded means that the adjacent surfaces of facing and backing materials are joined locally only, averaging over 10 to 20 per cent of the contact area.

There are four general methods used for manufacturing clad of the so-called integral type. These are as follows:

Casting method
Heat-pressure method
Fusion inter-melting
Continuous resistance welding

Three methods are used to produce partially bonded clad:

Plug welding
Spaced resistance welding
Strip welding

Of the integral clad steels all except the continuous resistance welding method involves hot rolling to final dimensions. The partially bonded clad steels are made by joining an alloy sheet to a base metal plate without further hot reduction.

Integral Clads

We shall now treat those processes in which hot mechanical working is carried out after the alloy steel is applied.

In the casting method, one metal in liquid form is usually poured around the solid second material. Usually the alloy is the solid material. The entire mass is then hot worked to proper plate thickness with properly proportioned alloy layer.

In the assembly method the materials are not in the liquid phase at any time in the cladding process. Two slabs of desired composition are selected with proper proportional thickness and one is placed upon the other, after which the edges of the two slabs are joined together by welding. The assembly is then heated to the rolling temperature and hot worked to desired gauge. Dependence for bond is entirely in the rolling operation.

There are four variations of the assembly scheme. In the one, the two slabs are placed together face to face with no other material in between. In a second variation, a thin sheet of iron is laid between the alloy and the plain carbon steel, and a third procedure consists of removing the oxide from the alloy by pickling and then electrolytically depositing iron upon the chemically cleaned surface. In a fourth variation, attempt is made to obtain bond by placing ferro alloys between the two materials before they are joined as an assembly.

In all of these processes it is usually the case that the assemblies are rolled double, in which case the two alloy faces of each assembly are put together with a parting compound between them.

In the fusion method of producing clad, alloy metal is added in the liquid state to the liquefied surface of the carbon steel base metal which is in the form of a slab or ingot. The added alloy steel facing is actually manufactured during the operation on the slab surface at which time a definitely controlled depth of the carbon steel base is liquefied with the result that what was one part of the carbon steel slab or ingot becomes an integral part of the alloy facing with proper composition. Dilution from the carbon steel liquification is anticipated and controlled. In the fusion process, thorough bond is wholly obtained in the joining operation. This is in contrast with all the previous discussed methods in which hot mechanical work is used after the clad is applied.

There are three variations of the fusion method for making clad steels. In the best known method, which is producing large tonnages, a refractory mold is built up to form three sides of an enclosure against the steel ingot or slab onto which the clad material is intermelted. Into this inclosed space the desired alloy is actually manufactured by a special electric furnace operation so as to produce an alloy layer of uniform and controlled composition. The result is an integrally bonded composite slab or ingot which is heated and rolled to gauge by the mill by routine procedure.

In a second variation of this method, alloys are placed on the surface of a steel slab or ingot and then interfused with base metal by means of a carbon arc.

In the third variation, extremely wide single beads of alloy composition are deposited at high amperages on the surface of an ingot or slab. Successive beads are deposited by the interfusing with the base metal at the bottom and to one side of the previous bead.

In all three of these methods bonding is definitely obtained in the fusion operation and hot rolling reduces the assembly to proper gauge.

The slabs or ingots veneered by this method are rolled singly to final dimensions or to some intermediate stage where the alloy surface may be inspected and conditioned. The advantage here is that the composite material may be inspected at any point where it is desired to stop the rolling.

Clads not Mechanically Worked

In the plug welding method, a thin sheet of proper composition of alloy material is placed upon a rolled carbon steel plate, holes having been drilled in the alloy steel sheet. The alloy steel sheet is then joined to the rolled carbon steel plate by hand welding from a coated alloy steel electrode. Hundreds of such welds must be made for any sizeable plate.

There are two variations of the resistance welding method. In one, a thin alloy sheet is attached to a rolled plate of carbon steel by spot welding a great number of resistance welds spaced closely over all the sheet. Penetration into the carbon steel actually takes place

at the weld. In another method, the resistance welding is carried out at every point of contact between the alloy sheet and the rolled carbon steel plate, the welds overlapping one another to cover completely the entire surface area. A pure nickel sheet is first laid on the rolled carbon steel plate and on top of this, alloy sheets of the proper composition are placed. The entire surface of the assembly is then resistance welded to form what may be called the continuous resistance welded product.

A third method of producing clad plate which falls in this group in which mechanical working is not carried out after the cladding is put on is termed "strip welding". In this method, alloy sheets are laid on the carbon steel base plate and the welding is carried out through a flux with an alloy wire of proper composition so as to join the alloy sheets to the carbon steel. The resultant product then consists of lined cells which are separated from each other by the welds.

All four of these products have the advantage of producing an alloy clad surface upon a rolled carbon steel plate, and all can be formed into shells and heads. They are not hot worked to reduce thickness.

The plug weld represents the poorest type of construction as it is practially impossible to make the great number of welds required without porosity and checks.

An objection to the spaced resistance weld is the fact that the bond is not continuous over the entire adjoining area between alloy and base metal. As a result, buckling and cracking may take place in high temperature service. Bond strength is low. Heat transfer is poor, and should corrosion take place through the liner, or should leaks occur due to cracks etc. at any given point, the corrosive medium easily will find its way through the entire structure to the carbon steel. In this type of product since no filler metal is added, dilution may take place at the bottom side of the alloy sheet with resulting low alloy composition, depending upon the actual amount of penetration into the carbon steel. This in turn results in a reduction of the remaining thickness of alloy which was of original composition. Carbon content may also be raised in the diluted zones with increase in hardness, loss in ductility and corrosion resistance.

In the continuous resistance welded product, it is claimed that the nickel sheet serves to prevent carbon steel dilution from taking place. In addition, there is considerably greater bond area than in the previously discussed product. However, this type of material would seem to be extremely expensive to manufacture because of the great amount of resistance welding which is required, also because of the high priced thin nickel and chromium sheets. In addition, the surface produced by the resistance welding tool is quite rough, which may result in excessive coke deposition in refinery service.

The strip welding method also possesses partial bond, but this product has a stronger bond than the spaced resistance weld, but not as strong as the continuous resistance weld. Composition of the weld material is satisfactory in this case, since the dilution from the carbon steel is controlled by the use of an alloy welding wire of proper alloying content. If leaks occur through the liner, the cellular structure confines the corrosion attack to one cell, in contrast to the spaced resistance weld. Some buckling from this type of product may also result in high temperature service.

Summary

It is thus apparent that the user of composite steels has at his disposal a wide variety of alloy surface compositions. As listed in Table I, it will be noted that the common alloy materials available run from 12% Cr steel as the lowest alloy to 25% Cr, 20% Ni steel in the stainless steel group, as well as pure nickel, monel, inconel and copper. These alloy materials protect against a wide range of corrosive conditions.

While the first use of present-day clad steels was in the pressure vessel field, where thick plates were required, compositions are also used today in considerably thinner gauges. Thus kitchen utensils, mess trays, and the like are being increasingly made from clad steels. It would seem at first that the only advantage is in the saving which results from less alloy being used than is the case if solid alloy material was originally chosen. However, where deep drawing is necessary, the clad steels have a tremendous advantage over the solid stainless steels in that considerably more deep drawing can be done without intermediate anneal. This is a boon to the fabricator. Another factor in favor of clad steels is the high conductivity of the composite material. This is an advantage in kitchen utensils and, therefore, to the ultimate user of the material. The field in which clad steels are used continues to grow, and it may be expected that considerably more of this type of material will be used in the future. This is particularly true today when the alloying elements are at such a premium.

The Discussion on the papers presented by Messrs. Blumberg and Theisinger can be found at the conclusion of Mr. Theisinger's article, page 80.

Welding, NICKEL, MONEL and INCONEL Clad Steels

. . . . clad steels are readily fabricated by welding, using a suitable welding electrode for the clad side depending on the cladding . . . .

By W. G. Theisinger

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COATESVILLE, PENNA.

Presented before A. I. S. E. PHILADELPHIA SECTION

▲ CLAD steels bridge the gap between the expensive, solid, corrosion resistant metals and the cheaper structural steels that may be used for vessels, tanks, and other operating or storage equipment. The development of the clad steels had a definite economical background by simply submitting a less expensive, yet equally suitable material of construction at a fraction of the cost per year of service life compared with the previous metal employed. Fundamentally, the factors dictating its use are based on the need of a corrosion resistant surface to withstand the chemical attack of the vessel's contents on the surface of the vessel and the necessary section thickness of the container to withstand the operating stresses. Such combination of requirements would demand a high cost pure metal or alloy in thickness perhaps of 1 in. or heavier so that the cost of the material alone might prohibit the commercial manufacture of a product. On the other hand, commercial steel would not withstand the corrosion long enough to pay for the equipment. In addition, freedom from contamination of the vessel's product is extremely important, even though the corrosive attack on the vessel is negligible. In this field, the clad steels are especially applicable.

A clad steel plate is a composite metal made up of a commercial grade steel plate to one side of which is uniformly and permanently joined a dense, homogeneous veneer or cladding of a corrosion and/or heat resisting metal the thickness of which is a substantial proportion of the total plate thickness. The corrosion resistant surface of this clad steel plate faces the contents of the vessel, and the structural strength of the vessel is attained by a combined thickness of commercial steel and cladding metal. Naturally, the price of this composite plate is much less than if solid corrosion resistant metal of the same section thickness had to be used.

Clad steels are available in many different compositions of both cladding metal and backing steel. Such grades of steel as A. S. M. E. S-1, S-55, (plain carbon steels of 55,000 and 70,000 psi minimum tensile strength) and the low alloy steels of the type of nickel, molybdenum, manganese-molybdenum, etc., have been clad with nickel, monel, inconel and stainless. Practically all the varieties of stainless steels and irons are available to be used as cladding metals. The usual practice is to clad these corrosion resistant metals on the plain carbon, flange quality, A. S. M. E. S-1, 55,000 psi minimum tensile grade of steel.

Clad steels are available in essentially the same sizes and gauges as commercial rolled steel. In Figure 1, is shown a one-piece plate of nickel-clad steel 152 in. x 151 in. x ¾ in., weighing 5,315 lb, that was used by one of the large chemical companies. Pressure vessel heads, flanged, flanged and dished, elliptical, hemispherical and coned shaped, are hot formed to A. S. M. E. and other specifications. Usually the cladding is on one side of the composite plate, but both surfaces may be clad

for such use as partitions in vessels. The commercial thickness of cladding is usually 10 per cent of the total thickness of the composite plate. For example, a total thickness of cladding and steel of 1 in., would have a steel backing .900 in. thick and a cladding metal of .100 in. thick in a 10 per cent nickel clad plate. However, the thickness of the cladding may vary from 5 to 50 per cent of the composite thickness, or the thickness of the cladding may be constant such as .031 in. regardless of the steel backing plate thickness. Thus, the designer or user has considerable flexibility in his selection of both composition and thickness of the cladding

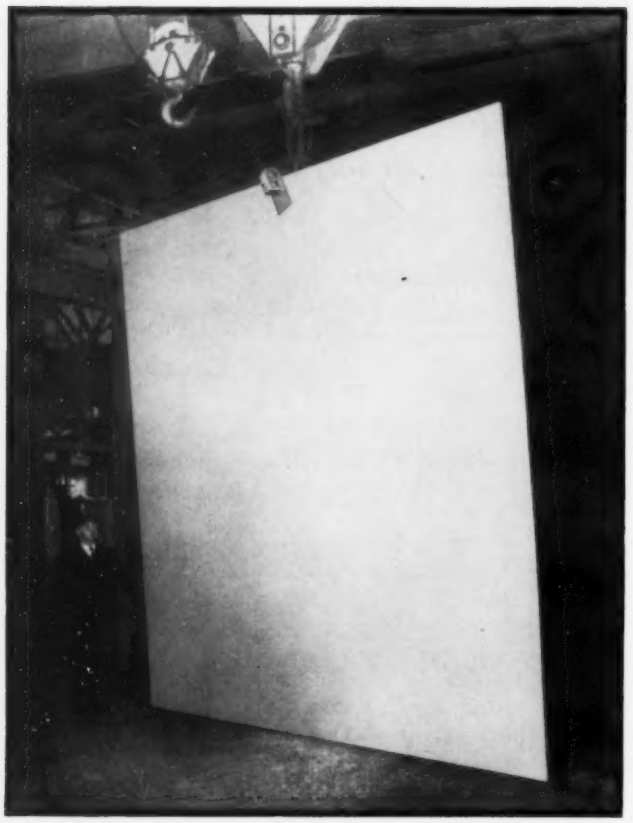


Figure 1 — This 10 per cent nickel-clad steel plate, 152 in. x 151 in. x ¾ in., was used in a shell for a chemical plant.

metal and steel for a particular design, as well as the shape of the structural member itself.

In this discussion, the interest is centered specifically on nickel-clad, monel-clad and inconel-clad steels with particular reference to welding procedures used in their fabrication. In general, these three clad steels are handled the same regarding fabricating tools and methods, excepting, of course, the adoption of a suitable welding electrode for the clad side depending upon the cladding present. Otherwise the beveling, forming, heating and other methods and precautions for working suggested, apply alike to all of them.

The first of Lukens' clad steels was nickel-clad steel which was developed in 1930 by the combined effort of the Lukens Steel Company and the International Nickel Company. This work sought to develop a material that would be economically available for tank cars for the transportation of iron-free caustic soda used in the rayon industry. While these first nickel-clad tank cars, because of transportation regulations, were riveted, the savings resulting from the use of clad steels over solid metals were still further increased by the application of welding. The cost of a riveted nickel-clad structure is high due in part to the need of solid nickel or nickel capped rivets. Obviously, welded fabrication has been an extremely helpful tool in furthering the use of clad steels.

In 1934, Lukens' inconel-clad steel was first produced for the winery industry, especially for equipment used in the production of high grade domestic champagne. Inconel-clad steel is also used considerably in the food and pharmaceutical industries. A typical analysis of inconel is 80 per cent nickel, 14 per cent chromium and 6 per cent iron. The latest addition to Lukens' clad steels, monel clad was developed primarily to meet certain needs of the salt industry for increased resistance to sulphuric acid. It is also used in the manufacture of pharmaceuticals and in the oil industry. Monel is composed of 67 per cent nickel and 33 per cent copper.

In clad steels, the nickel, inconel and monel claddings contribute added strength to that of the backing steel. The minimum physical values for nickel-clad, inconel-clad and monel-clad steels are:

Tensile strength . . . . . 55,000 psi minimum
Yield point . . . . . 27,500 psi minimum

The designing of equipment for clad steels follows that for similar equipment in commercial steel. Since the thermal coefficients of expansion of the corrosion resistant metal and steel are approximately alike and, as temperature changes within the range in which the corrosion resistant metals and steel can be used do not affect the bond, these clad steels provide maximum thermal efficiency in heat transfer equipment. The designing of equipment is also aided by the availability of the large plates that can be rolled of these clad steels.

For example, clad steel plates 1 in. thick may be supplied in one piece up to 138 in. square or 335 in. long x 60 in. wide and plates ½ in. thick may be obtained up to 480 in. long x 84 in. in width or plates 162 in. square.

Nickel-clad, monel-clad and inconel-clad steels are made by the heat and pressure method which produces a permanent and efficient bond between the cladding metals and the steel base plate. These composite slabs are put together in sandwich form, heated to 2300 F, and rolled in a heavy plate mill under tremendous pressure. This pressure on the white hot composite assembly reduces its thickness while plastically bonding the cladding and the steel together. This method protects the surface of the cladding from contamination during hot rolling.

The efficiency of this rolled bond is demonstrated by the test illustrated in Figure 2 which was devised to yield quantitative data of its strength. A tensile test of this kind is readily understood and its values given in pounds per square inch tensile strength are comparable to normal design calculations for structural steel. The failure of the composite plate in the steel portion

demonstrates that the strength of this nickel-to-steel bond is stronger than the steel itself.

Welded Fabrication

The many hundreds of tons of these clad steels that have been fabricated indicate that this work can be done in any commercial shop employing reasonable care and supervision in the fabrication of any of its products. The customary precautions employed for any quality material by the fabricator will not need any great modifications in the handling of clad steels.

In order to protect the clad surface during shop operations, it is suggested that care be exercised to avoid marking or scratching the surface. This will also prevent the possibility of embedding iron particles into the clad surface that might cause corrosion at this point in service later. The top roll for forming the shells should be cleaned or covered with paper to prevent contaminating the surface of the cladding by iron particles from the rolls. The clad plate should be moved around the shop to the shears, etc., with the clad side up to protect the surface of the cladding.

The edges of the composite plates are beveled for welding by machining in the usual manner, as shown in Figure 3. One of the important changes necessary in the welding of most clad steels must be taken into account at this point because of possible metallurgical reactions. In most cases, the steel should not be beveled to include the cladding in the bevel and some steel should be left in the lip above the cladding before starting the bevel. While the steel side is welded with a commercial steel electrode and the clad side with the appropriate nickel or nickel alloy welding electrode, the procedure to be followed in the deposition of the first steel bead in the bottom of the groove is extremely important. This bead should be run with the amperage on the low side of the recommended current range so that the metal is deposited "cold" and penetration will not be excessive. If the first steel bead penetrates and absorbs the cladding metal, the steel bead will become hard and subject to cracking. This pick up of the cladding metal into the steel weld metal produces a martensitic structure which results in high hardness and low ductility of the weld metal. The first bead may crack requiring chipping and rewelding, or it may be just hard enough to lower the ductility of the completed weld to a degree that it will fail to meet the required elongation during the physical testing of the welded coupons. However, this difficulty is avoided by leaving $\frac{1}{16}$ in. steel in addition to the cladding thickness, and at the same time running the first steel bead "cold" in the bevel between the edges to be joined.

For plates up to $\frac{1}{2}$ in. thick, the straight "V" groove with a 70 degree included angle is preferred, whereas, for plates $\frac{1}{2}$ in. and thicker the "U" groove should be used, as shown in Figure 3. The same machine tools and methods employed for steel should be used for the beveling of clad steels. The abutting edges should fit together with the same accuracy as required for any quality workmanship, such as the boiler code and similar specifications. In fact, the offset between the meet-

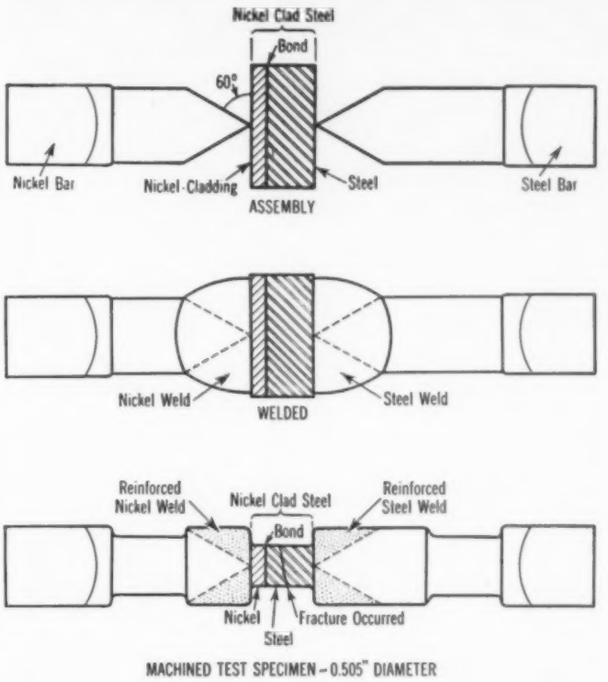


Figure 2 — Sketch showing test piece in which the break occurred in the steel portion at 55,000 psi without affecting the bond.

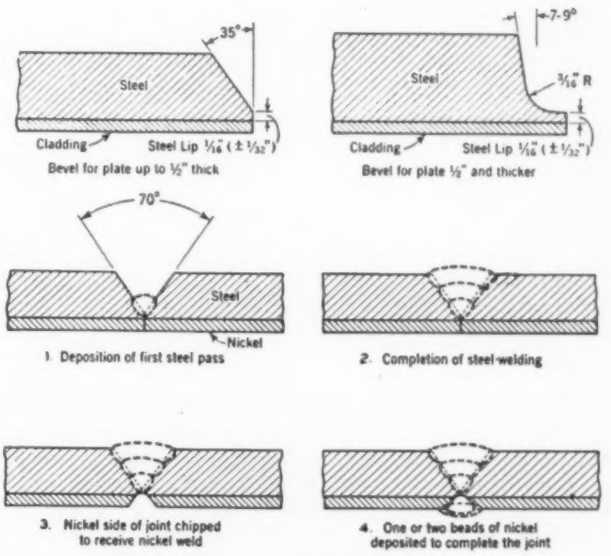


Figure 3 — Sketch showing welding sequence for nickel-clad steel plates.

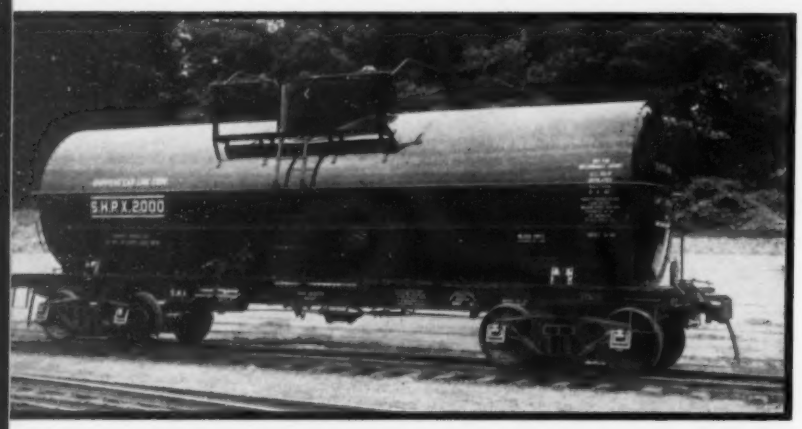


Figure 4 — One of five all-welded 10,000 gal nickel-clad steel tank cars, built to I. C. C. specification 103-W.

ing edges should not be greater than the thickness of the cladding, or closer if possible. The code requirements stipulate that such alignment tolerances must be held; and they should be maintained not only for appearance, but also to prevent the pick up of the cladding metal in the deposition of the first steel bead. Such pick up can occur if the offset is great enough to expose the cladding to the first steel bead as it is being deposited. Although the fit-up requirements are no more stringent than those for ordinary steel, carelessness in fit-up should be avoided at all times whether limitations are imposed or not.

The first steel bead is deposited in the bottom of the groove with the same care as in the welding of regular quality steel, with the additional precaution that penetration should be carefully controlled. As in any ordinary steel, each bead is brushed to remove the welding slag, and the succeeding beads are deposited to fill the groove. In the welding of plates up to 1¼ in. thick, the steel side may be completely welded before chipping and welding the clad side. However, for plates heavier than 1¼ in., it is at times helpful to only partly fill the steel groove and, without completing it, chip and weld the clad side, to be followed by completing the steel side of the joint. This practice reduces the amount of warping and overcomes the tendency to cracking as a result of the extension of the unfused area in the form of a stress crack up through the steel bead.

While other methods of welding, such as oxyacetylene, carbon arc and atomic hydrogen, may be used for the welding of clad metals, the preferable method and the one most commonly used is the metal arc method. Electric arc welding is especially desirable when welding the nickel side, as the conditions are much easier to control.

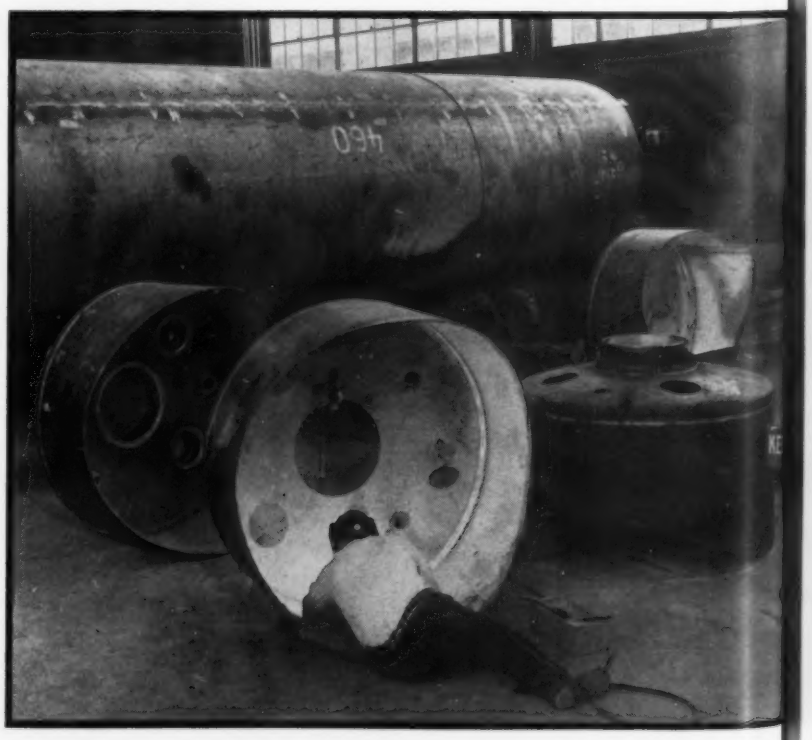
Following the rolling of the clad plates to cylindrical shape and the alignment of the abutting edges, the vessel should be tacked with steel electrodes on the steel side. In normal practice, the first steel bead should be deposited with care as described above, and all beads on the steel side of the joint should be deposited with qualified plain carbon steel, covered electrodes to completely fill the groove.

The joint is then chipped from the clad side to clean sound weld metal using a 3/16 in. or ¼ in. round nose gouge. Chipping is continued until the chip no longer splits, indicating that the lack of penetration has been chipped out. The groove should be kept as narrow and shallow as possible. While the unfused area at the bottom of the steel weld in the joint must be chipped out to solid metal, excessive chipping is not only costly from standpoint of labor but also requires unnecessary amounts of costly nickel weld metal to be deposited in the groove.

A bead of pure nickel electrode or nickel alloy depending upon the type of cladding is deposited into this chipped groove. The first bead should just about fill the groove and the slag worked to the top to cover the bead. Slag trapped along the side of the weld in the joint will be hard to remove and the resulting void will be difficult to fill with weld metal by the overlapping bead. Therefore the welding amperage, voltage and speed of welding should be practiced by the operator prior to the welding of the vessel itself so that the operator is acquainted with this nice adjustment between these three factors that make the difference between successful and poor welding techniques.

Due to the fact that the cladding is pure nickel, for example, and it is desirable to maintain that same purity in the weld metal, two beads of nickel would be deposited on the nickel side of the joint by having one bead in the groove and a second or cover pass over it. The first nickel bead always picks up some iron due to its contact with the steel base plate, but this iron contamination is diluted to negligible amounts in the cover pass which will be in contact with the contents of the vessel. The second bead should slightly over-lap the

Figure 5 — View showing the welding operation on the nickel side of the nickel-clad steel dome.



width of the first bead and at the same time not undercut through the cladding to the steel. Prior to depositing the cover bead, the tightly adhering slag of the first nickel bead must be carefully removed. The slag adhering to the cover bead should be thoroughly removed as these slags may be the cause of corrosion if allowed to remain on the bead when the vessel goes into service.

It is necessary to use a somewhat higher amperage in depositing the first nickel pass in order that the slag will be washed or forced out of the groove. However, the amperage should be decreased and the voltage increased slightly when depositing the cover bead to eliminate the possible formation of porosity in the nickel weld. In welding nickel or its alloys, it must be kept in mind that there is not the latitude in amperage, voltage and welding speed as there is with commercial steel, and that these variables must be controlled much more closely than the welder may be accustomed to, especially if the vessel is subject to x-ray inspection. Porosity is usually caused by excessive amperage, whereas fine pepper porosity is due to too slow a welding speed. Solid welds as indicated by x-ray inspection are most readily attained by high welding speeds with low amperage and voltage values.

In the welding of any material, undercutting alongside the weld has become a difficulty of considerable importance, but with clad metals, special care should be given to avoid undercutting. Undercutting will not only affect the mechanical structure of the joint, but by penetrating through the cladding into the steel backing will expose the iron to attack.

The clad side is usually welded with two beads of nickel or nickel alloy weld metal and in most cases it would require two beads to produce a reinforced joint. However, the two bead weld for the cladding serves another purpose in that the pick up of iron from the base plate as the first nickel pass penetrates it may be largely confined to that bead, while the cover bead in diluting it produces a very low iron content in this cover bead. The small pick up of iron may be made use of by substituting for the pure nickel rod an alloy rod of 80 per cent Ni-20 per cent Cr which when used to weld on the clad side of nickel-clad steel will dilute the nickel, chromium and iron to the approximate proportions of 80 per cent Ni, 14 per cent Cr and 6 per cent Fe or the typical analysis of inconel. This alloy is one of the commercial corrosion resistant metals.

This 80 per cent Ni-20 per cent Cr welding electrode is used for the welding of inconel-clad steel and the welding procedures and the other fabricating methods described for nickel-clad steel should likewise be used on inconel-clad steel with the appropriate nickel alloy rod supplied under the name of inconel electric arc welding rod.

Monel-clad steel should be welded with monel electrodes suitable for monel-clad steel and are furnished under the name of monel arc welding rods. The same procedures for fabrication and welding as given for nickel-clad steel should be applied to the fabrication of monel-clad steel.

At times a design may require the joining of dissimilar metals, such as, nickel-clad steel to ordinary steel, and the problem of the correct welding electrode may be solved by the use of a pure nickel rod. While such a joint is sufficiently strong for the purpose, a stronger and more ductile weld may be obtained by the use of the monel arc welding electrode where either nickel or monel-clad steels are to be joined to steel. Such joints occur at partitions or in other areas where the extension of the cladding need not be carried to the top of the structure.

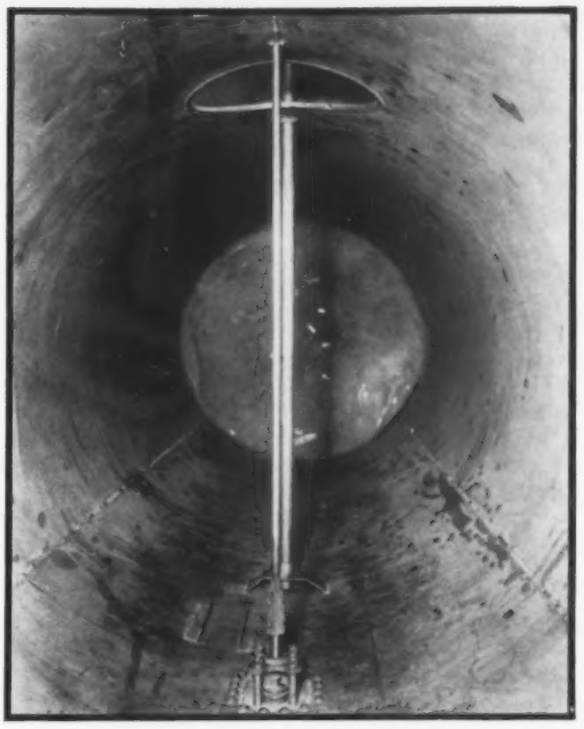


Figure 6 — Interior of all-welded nickel-clad steel tank car. The car is heated by external coils and is insulated with 6 in. of fibre-glass.

One of the recent Class I welded structures has been the fabrication of five all-welded nickel-clad steel tank cars built at Milton, Pennsylvania, by the American Car and Foundry Company. These tank cars are of the 10,000 gallon type built to I. C. C. Specification 103-W, as illustrated in Figures 4, 5 and 6. The straight seam welds in the shell as well as the circumferential welds joining the heads to the shell were completely x-rayed after stress relieving. The steel side was welded by an automatic process and the nickel side deposited by hand with covered pure nickel electrodes. The x-ray examination included the complete joint of nickel and steel welds and revealed less than 1 per cent cutouts. These excellent results were obtained because of the control exercised over such variables as welding speed, amperage and voltage for both the steel and the nickel welds in the joints. The welders knew exactly what conditions to use as the procedures had been worked out very carefully before any welding was done on the tank cars.

The stress relieving of welded nickel-clad, monel-clad and inconel-clad vessels may be done by the same methods and treatment as employed for steel, namely: Heat to 1150-1200 F and hold at that temperature for one hour per inch of thickness. No modifications of the usual practice for steel are required. However, as in the

stress relieving of any welded material it is particularly important to heat slowly to the stress relieving temperature where the joining of unequal thicknesses has been done, or if the design is such that slow heating is required to bring about uniform temperature at all times throughout the vessel.

DISCUSSION

PRESENTED BY

N. C. BYE, Chief Engineer, Henry Disston and Sons, Inc., Philadelphia, Pennsylvania

W. H. JOHNSON, Development Engineer, Bethlehem Steel Company, Sparrows Point, Maryland

C. M. THOMPSON, Sales Engineer, Henry Disston and Sons, Inc., Philadelphia, Pennsylvania

BASIL OSMIN, Welding Supervisor, United Engineers and Constructors, Inc., Philadelphia, Pennsylvania

STUART B. MATHEWS, Edgecomb Steel Company, Philadelphia, Pennsylvania

MARTIN J. CONWAY, Special Engineer, Lukens Steel Company, Coatesville, Pennsylvania

H. S. BLUMBERG, Metallurgist, M. W. Kellogg Company, Jersey City, New Jersey

W. G. THEISINGER, Director Welding Research, Lukens Steel Company, Coatesville, Pennsylvania

N. C. BYE: I would like to know from Mr. Theisinger whether the electric welded joints (of the sandwich pile for roll welding) are made continuous to exclude air from between the surfaces when heating for rolling so oxides are not formed which will interfere with the roll welding operation. Also, does the uneven flow of two dissimilar metals cause any trouble in the rolling operation itself, so that the harder or softer center section either goes beyond or stays inside of the surface sections?

In the case of non-ferrous clads, is it necessary to stress relieve in the electric welding operation, as it is necessary in the case of the ferrous clad materials?

I would like to ask Mr. Blumberg if it is ever necessary to do mechanical working of the weld sections to supplement any grain refinement you may get from heat treatment? And also, in the casting method, are any precautions necessary to prevent oxide formation on the alloy inserts which may tend to make bad welds?

W. H. JOHNSON: I have a few questions I would like to ask. I would like to know whether the effect of expansion and contraction has any radical effect on your bond and whether it is actually necessary to do any heat treating to relieve stresses after shearing these plates?

You mentioned the fact also that you sandblasted or thoroughly cleaned the steel plate. Do you also do any special cleaning or removing of oxide on nickel, monel or copper? I understand that monel metal is extremely difficult to work, and the assumption is that on welding, we might get quite a lot of cracking along the weld metals. Another thing that I have run into in connection with nickel or some of these alloys, is furnace atmosphere. It is easy enough to see that where you pile one steel plate on top of another and exclude air and the furnace atmosphere, in rolling you are not affected by same; but I would like to know what has to be done for flanging operations, where the nickel may be exposed to furnace temperature and atmosphere.

Is there a tendency for the cladding to harden the base metal, or rather what I want to say, is there a dilution of the nickel or other cladding into the iron, causing brittleness?

You also said it was extremely important on your preliminary welding to stay outside of the nickel cladding range. It was indicated that cladding was cut out and bevelled for your nickel application. Is there a dangerous pick-up of iron or a dilution in your first bead on your nickel side, and if so, is there any tendency for the pick-up to cause corrosion.

On stress relieving nickel clad material, after it has been fabricated into vessels, is a localized stress relieving satisfactory, or is it necessary to stress relieve the entire vessel, especially on vessels such as are used in oil refinery equipment, where the material may be extremely heavy?

One other question: You mentioned the fact that you have produced a plate, 152 in. x 152 in. x ¾ in. This of nickel clad material — what is the heaviest plate that you are able to produce and really get a bond in comparison to what you have shown here?

C. M. THOMPSON: One thing came to my mind, and that is whether or not the introduction of copper in the carbon steel backing was any advantage in increasing the bonding?

BASIL OSMIN: I understand from Mr. Theisinger that chemical industries and paper industries use quite a lot of clad plate material. I should like to see the pipe mills take advantage of the situation and produce more clad pipe.

Also, I have a question on the welding of dissimilar metals. In welding together two lengths of pipe of dissimilar metals with a single V butt joint, I have the following cases: (1) One end of pipe is A-206 carbon molybdenum, the other end is A-106 carbon steel; (2) one end is carbon molybdenum, the other end is 18 per cent straight chrome; (3) one end is 18 per cent straight chrome, the other end is 18 per cent chrome, 8 per cent nickel. What welding electrode would you use in these applications?

S. B. MATHEWS: Assuming you were making a deep draw of duel clad 18-8 stainless steel with a soft steel center, when it is necessary to anneal between draws, how would you anneal it?

M. J. CONWAY: I wish to ask one or two questions by way of bringing out more information. What minimum diameter of flanging necks are recommended when connecting flange connections of like clad plate in pressure vessels fabrication?

Where clad plate is used for heat exchanger tube sheets, what are the minimum clad thickness requirements immaterial of the total tube sheet thickness?

Using a tower as an illustration where liquid may be in the lower portion and vapor in the upper portion, and corrosion effect may be dissimilar in these two sections, does Mr. Blumberg or Mr. Theisinger know if two different clad metals have been used in these sections to relieve the different corrosion effects?

In view of the different coefficient of expansion of some of the clad metals and the backing up plate, what are the recommended peak operating temperatures of the several clad plates discussed?

H. S. BLUMBERG: I believe Mr. Bye asked whether there is any necessity for mechanically working welds. That is not common practice, except for the practice called "peening." In depositing certain weld materials it may be desirable to cold work the metal, because recrystallization takes place on heating with subsequent grain refinement at lower temperatures. Otherwise, working is not purposely done. The reason for this is that with X-ray equipment available today, with the excellent carbon steel and alloy welds which are obtainable, with the massive supply of data on the physical properties of welded joints, in addition to laboratory corrosion data, and, last but by far the most important, with the excellent record of clad materials in service, there appears to be no reason for going to hot mechanical working.

With certain materials which have no critical points, if you cold work the material, subsequent heating may give you some grain refinement. Working also will close blowholes to a degree. In addition, you get some stress-relief.

With regard to Mr. Osmin's question about the welding of dissimilar metals, I would like to point out the care necessary in answering this type of question. Mr. Osmin stated a very general question but asked for a decidedly specific answer. For such a specific answer it is necessary to have somewhat more information. However, let us see what can be done with these questions as stated. For example, in the joining of A-206 carbon-molybdenum steel to A-106 plain carbon steel, a metallurgist or mill man knows that when you have molybdenum in the steel it is undoubtedly being used for strength at temperature. Now, if the designing engineer is satisfied to use carbon steel at any given location, it must be that he does not have the temperature problem at that location. Therefore, I would say that these two steels can be joined by using either a plain carbon steel welding electrode or a carbon-molybdenum steel electrode. Let us take the second case, in which it is desired to weld carbon-molybdenum steel to 18 per cent straight chrome steel. Again, the metallurgist knows that 18 per cent chromium steel is used primarily where extreme corrosion is a factor, and again, if the designing engineer uses carbon-molybdenum at a given location, it must be that the corrosion problem does not exist at that point. From an economic point of view it would seem that a carbon-molybdenum electrode is indicated. However, the weld metal would pick up considerable chromium from the 18 per cent chromium side and, therefore, there would be produced a very hard deposit. It would be my recommendation, therefore, that a 25-20 chromium electrode be used for this joint.

Take the third case, in which it is desired to join 18 per cent straight chrome with 18 per cent chrome-8 per cent nickel. Here a 25-20 electrode should be used because of the excellent physical properties and toughness of such weld metal. Under no circumstances should a straight 18 per cent chrome electrode be used as such a deposit is apt to be quite brittle.

W. G. THEISINGER: The assembly is made up of two A. S. M. E., S-1 grade steel base slabs; on top of each is placed a plate of pure nickel. A parting compound is spread over the surface of the nickel, so that the nickel plates do not weld together during rolling.

Each plate of nickel is welded to a steel slab simply to hold it in place. A steel bar is placed into the groove between the steel slabs and the slab welded together on all four sides so that it is sealed before the heating and rolling operations. After rolling, the plate is sheared and separated into two plates of nickel-clad steel. Does that answer the question?

N. C. BYE: Yes. In the rolling operations is there any relative movement with the nickel trying to go out beyond the steel?

W. G. THEISINGER: The working temperature range of nickel and steel are very close together. Actually the melting point of steel is 2750 F and that of nickel, 2640 F. The rolling temperature for nickel is in the vicinity of 2300 to 2350 F, the same as for steel, so that we have equal elongation, reduction in thickness, or spread, as the bi-metal slab is rolled into plate form.

As a matter of fact, we can start out with 10 per cent of the total thickness of nickel in the original assembly and end up with 10 per cent nickel to 90 per cent base steel in the final assembly. Nickel possesses the excellent advantage of having the same rolling and working properties as steel. In addition, the coefficient of expansion of nickel and steel are practically identical.

By comparison, copper offers a different problem in these respects. The melting point of copper is of course much lower than that of either nickel or steel. Where we roll the assembly of nickel clad in the vicinity of 2300 F, and can heat and roll the original slab to the form or thickness desired, copper cannot be heated over 1600 or 1650 F, which would soon become too cool for the rolling of the steel portions. Copper requires frequent heating and rolling operations to bring it to plate sizes.

However, with nickel and steel, we can roll both at 2350 F by heating the slab once and bring it to gauge with practically the same draft as we use on commercial steel.

As to the necessity for stress relief, if you would have to stress-relieve the vessel if it were made of steel, stress relieve the nickel clad vessel also. However, again because of the co-efficient of expansion of nickel and steel being very close together, the same stress relieving treatment applies to nickel-clad as is used for ordinary steel. In other words, heat to 1150 F or 1200 F for one hour per inch of thickness.

There is one particularly important item in connection with closed vessels in which there are a series of tubes, running through it to the headers. We always talk about a long cooling cycle from the stress relieving temperature. However, it is particularly important that we heat slowly in a rigid structure such as this. That applies to steel or clad vessel alike. In other words, where there may be poor heat conductivity through the vessel parts, outside sections may be up to a temperature of 600 F, if we heat quite rapidly, but inside the vessel it may be only 250 F. Unequal heating may cause cracks in the welded joints, whether it is a clad vessel or one of steel. So it is exceptionally important in rigid structures to heat uniformly as well as cool uniformly. Pay particular attention in heating, as you are going up to the stress relieving temperature.

As to the rolling effect on the bond, actually we feel

that we get our bond with the first few passes, and that further rolling from then on only helps to increase the strength of the bond.

As a matter of fact, we have rolled some plate two and three-eighths inches thick recently, 10 per cent clad, for Shasta dam, and the bond tests were very satisfactory. The heaviest nickel-clad plate that we can produce will weigh about 24,000 pounds.

In preparing the slabs, we clean the steel side by grit blasting and scrub with carbon tetrachloride to remove all grease or other foreign substances from the surface. We also sandblast the plate of nickel before we assemble it on to the slab.

As to the cracking of welds in monel, I don't know of any cracks that we have ever had as far as monel-clad steel is concerned.

As Mr. Blumberg pointed out, in the welding of dissimilar materials, where the first steel bead may pick up the nickel or stainless, whatever the cladding may be, into this first steel bead, the weld may be quite hard, unless precautions are taken to overcome this difficulty.

The same thing could happen with monel clad or any of the clad steels I know of — cracking occurring by picking up the cladding metal in this first steel bead, and thus making it martensitic. The first steel bead should not penetrate into the cladding from the steel side.

W. H. JOHNSON: I don't think that you quite had the idea of what I was trying to bring out. To begin with, the first bead you have in the bottom of the groove — suppose that didn't reach the nickel cladding at all, but after you had cut it out and put in your nickel, is there any dilution in the other material, of the steel into the nickel?

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W. G. THEISINGER: We are not bothered with this problem from the steel side then. We are chipping back from the nickel side. We do pick up iron in the first bead of any type of clad steel. After all, our chipping exposes the steel, and if we get any welding of our nickel electrode and our steel base plate, we have to mix the two metals, and so this iron contamination results.

Now, that particular metal isn't at all brittle; in fact, the high nickel-iron alloys are quite ductile.

The first nickel bead is diluted with some iron, but by putting a cover bead over this, which is the general practice, the iron is kept in the neighborhood of 5 per cent or 6 per cent. Thus we take care of the iron with two beads of nickel, the first picking up the iron, and the second diluting it by the further addition of nickel from the electrode.

W. H. JOHNSON: Does that tend to corrode?

W. G. THEISINGER: If it is high in iron.

W. H. JOHNSON: I mean for milk trucks or anything like that, where you use nickel clad material in the milk truck head where you make your joints? Is the iron in there low enough that there is no tendency for corrosion?

W. G. THEISINGER: It depends on service. You could go up to twenty per cent iron if necessary and still have a sufficiently corrosion resistant alloy for caustic uses.

For some services the iron must be kept under ten per cent. You can determine whether one bead which will keep the iron under twenty per cent is good enough, or whether we must put two beads on and keep the iron under ten per cent, or whether we have to go to special means to have less than even five per cent iron.

H. S. BLUMBERG: Isn't there some connection between dilution and diameter of weld rod?

W. G. THEISINGER: Yes, by manipulation of the electrode or selection of electrode. Inconel is an excellent corrosion resistant alloy. It is composed of eighty per cent nickel, fourteen per cent chromium and six per cent iron. If you start out with an 80-20 rod, (eighty per cent nickel and twenty per cent chromium), we do something like the stainless people do, who use a 25-20 rod, and count on the dilution to bring it down, say to around eighteen-eight.

The chromium is diluted and oxidized to some extent, and the five per cent iron pickup, produces an alloy similar to inconel.

The slab assembly protects the nickel from furnace conditions. In making up the sandwich assembly with nickel, and nickel and steel, welded together, the rolling is all done, and all the heating contact, of course, is on the steel side. The rolling is all performed on the steel; and the nickel or monel or inconel, all made by this method, never touch the rolls or are never exposed to the air from the time they are put into the assembly, until they are finally cut apart after heating and rolling.

When we flange heads, we cover the nickel surface with a compound that protects it. In addition, the sulphur content of the fuel is kept very low, less than one-half of one per cent.

Regarding the question of the lack of ductility in the tensile bored test — we realize that the $\frac{3}{4}$ inch length of the specimen does not permit the usual elongation.

There isn't the opportunity to elongate, as there isn't enough length there to help us get sufficient reduction of area to show ductility. In other words, if we made this test only an eighth of an inch in gauge length, we would have an abnormal tensile strength, with low ductility. The chance to neck down is not present, so that as we reduce this gauge length we also reduce our ability to elongate and show ductility. The design of the specimen plus the direction of testing, accounts for some of this lack of ductility.

As far as stress relieving the vessel by either complete stress relieving or local stress relieving, it is better to stress relieve the entire vessel uniformly. That applies to steel as well as to a clad; local stress relieving, unless it is done carefully, doesn't help very much.

Local stress relieving may set up a stress condition that would be practically as bad as that developed in our original welding. So that we should stress relieve uniformly by heating the entire vessel to 1150 F and cool slowly; or if the structure is such that we can't put it into a furnace, then taper the heat from the joint on out over the structure. It applies, I think, to steel or clad as well.

Mr. Thompson asked a question on the effect of copper on the steel in the bond, is that right?

C. M. THOMPSON: I had in mind where you were using nickel or inconel in clad, where the copper would have any tendency to increase the tendency of the bond.

W. G. THEISINGER: I don't know that we have

ever made any particular point in controlling the copper, to show its effect on the bond. I don't think, in the normal percentages that we run into that it would make any difference. We did clad a 2 per cent nickel, 1 per cent copper, low-alloy steel and it didn't make any difference as far as the strength of the bond was concerned. In that case we had 2 per cent nickel, with copper; but we have not tried it with copper alone. Perhaps you have some thought on it.

C. M. THOMPSON: I was just thinking of affinity of the copper for the nickel, whether it would make any stronger bond between the nickel clad and the carbon steel backing.

W. G. THEISINGER: I don't know. We obtain an iron-nickel alloy bond between the nickel and steel.

H. S. BLUMBERG: May I comment? I think you may be worse off with the copper backing material. It seems the heat pressure method is perhaps analgous to forge welding. Pure iron forge welds best. One of the patented processes for making clad steel is by the heat pressure method, in which the plated electrolytic iron is used.

Our company has had a lot of experience in forge welding dating back to early days, twenty years back and more. We found that as alloy content increases, and as carbon goes up in the materials forge welded together, that you got a poorer bond. It seems to me, therefore, that you might get slightly less bond, the more alloy material and the greater the carbon in the backing material in the heat pressure method of cladding. That's merely a guess, however.

W. G. THEISINGER: We expect to produce clad tubing with either the cladding on the inside or outside of the tube. The continuous welding of a clad-steel tube depends upon the leveling of the edges prior to welding. This work is in the development stage at present.

Yes, there are some instances where a clad steel is joined to a commercial steel. The joint may be made by welding the nickel to the steel with a monel electrode, or by the use of a nickel electrode, or by chipping beneath the nickel cladding to remove it and then welding steel to steel with a commercial steel electrode. The use of a monel electrode is preferred.

In answer to Mr. Conway's question regarding flange connections generally five and a half inch pipe is about the smallest that we have made so far by manual welding.

Where we have the problem of seating tubes in heat exchanger headers the tube should be rolled so as to maintain a continuous surface of the nickel over the tube without danger of cutting through the cladding. The cladding should be about $\frac{1}{16}$ inch thick.

In welding, it is particularly important, that undercutting be avoided with any clad material, as it not only produces a "notch" alongside the weld, but in addition, exposes the steel base plate to the action of the vessel's contents, resulting in corrosion alongside the weld.

In the forming of clad steels, the same limits apply to them as to steel. The minimum inside corner radius that can be bent is about equal to the thickness of the material, half inch plate can be formed to inside corner radius of half inch. Very sharp bends have been made; for example, quarter inch thick nickel-clad steel with the cladding on the inside has been formed to a quarter inch radius in the corners.

H. S. BLUMBERG: I neglected one question, I see. Someone asked what annealing temperatures were to be used after deep drawing. For the steels in the plain high chromium group, anywhere from 1350 F and perhaps 1450 F to 1500 F, with heating for thorough soaking, and then furnace cooling should be used. For the high chromium-nickel steels, by and large, heating to 1800 F, to 1850 F or above, and rapidly cooling is recommended. Does that answer your question?

I believe someone raised a question about the molybdenum austenitic steels. For these steels, some mills are recommending a stabilizing treatment of about 1650 F, and in some cases, up to 72 hours hold.

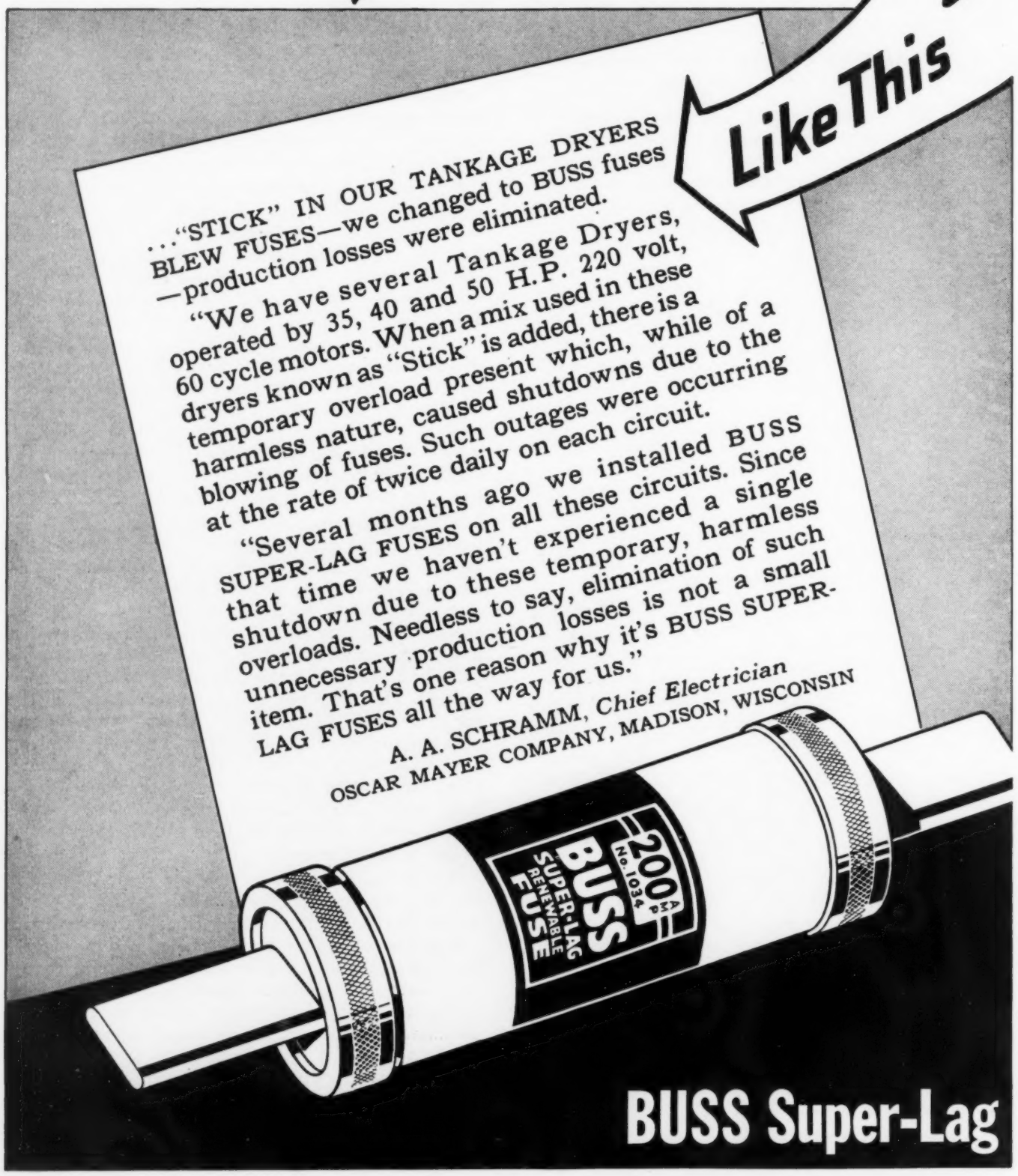
With regard to the question of stress-relieving, it is undoubtedly true that the chief value in stress-relieving lies in getting rid of locked-up stresses, but I think we know this, also that carbon in solution tends toward greater strength, greater hardness and less ductility. Stress-relieving temperature does not give a structural change in the sense that there is any change in grain size, but carbon may be precipitated out of solution, and we have found in laboratory tests that ductility is thus increased in the weld metal. I would answer the question by saying that I agree, stress-relieving does have its chief advantage in getting rid of mechanical stresses, but in addition to that, I believe it puts the metal in such condition that it can stand more deformation than if it had not been stress-relieved.

The question regarding stresses in clad materials is hardly a simple one. There is more than one school of thought in making such analysis, and I believe that some engineers could prove theoretically that under certain conditions composite materials should fail in service. That they do not, indicates that theoretical stress analysis without taking into consideration what actually happens in service, should be used with great caution. That does not mean one should rush in and use a vessel of clad steel without consulting the mechanical engineer. The subject is extremely involved, and could easily be the basis for long discussion. I think the thing to remember most is that composite or clad vessels have an excellent record in service, which means that intelligence has been used in the selection of and design of materials.

The problem of welding composite steel with a stainless clad surface is simpler than the welding of a composite where pure nickel is the facing. The reason is that in stainless composites, both the facing and the backing material have a considerable percentage of iron, whereas with a pure nickel, or pure copper, or pure silver facing, the surfacing material is nearly 100 per cent pure. Since the ideal in welding is to produce an integral joint, it can be seen that it will be difficult to weld on the pure metals, nickel, copper and silver, without some iron contamination. In the case of the stainless clads, however, it is possible to obtain a rod which is higher in alloy content, in most cases, than the surfacing alloy steel, and thus anticipate the iron dilution which occurs.

A MEAT PACKER

....by Reducing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"Several months ago we installed BUSS SUPER-LAG FUSES on all these circuits. Since that time we haven't experienced a single shutdown due to these temporary, harmless overloads. Needless to say, elimination of such unnecessary production losses is not a small item. That's one reason why it's BUSS SUPER-LAG FUSES all the way for us."
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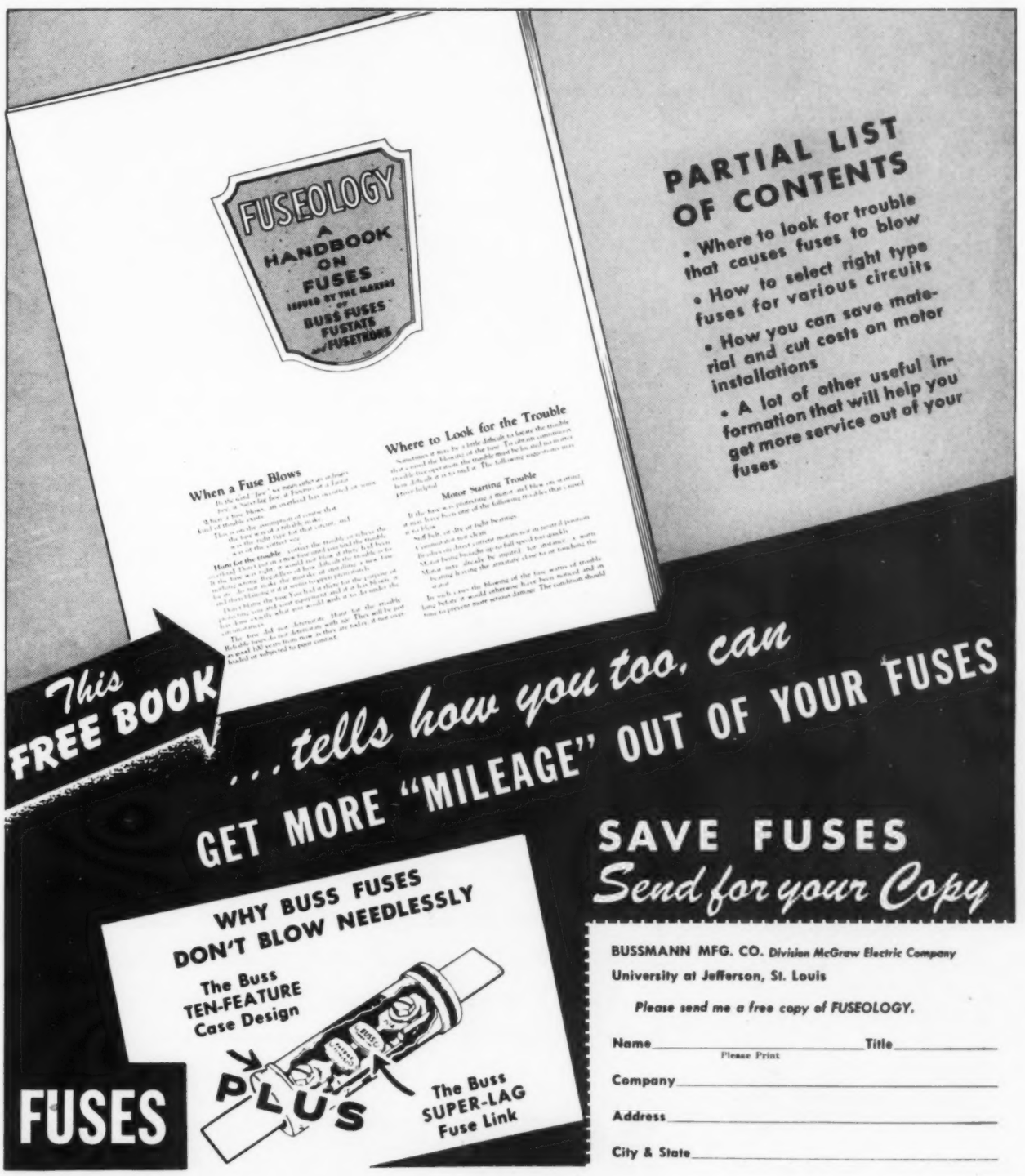
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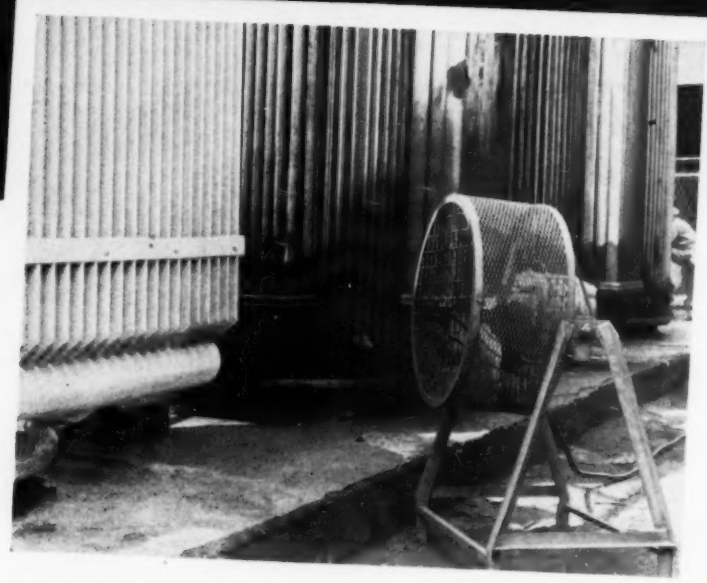

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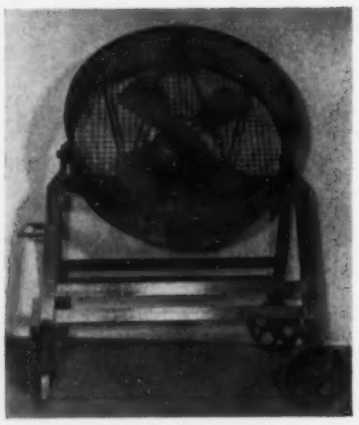

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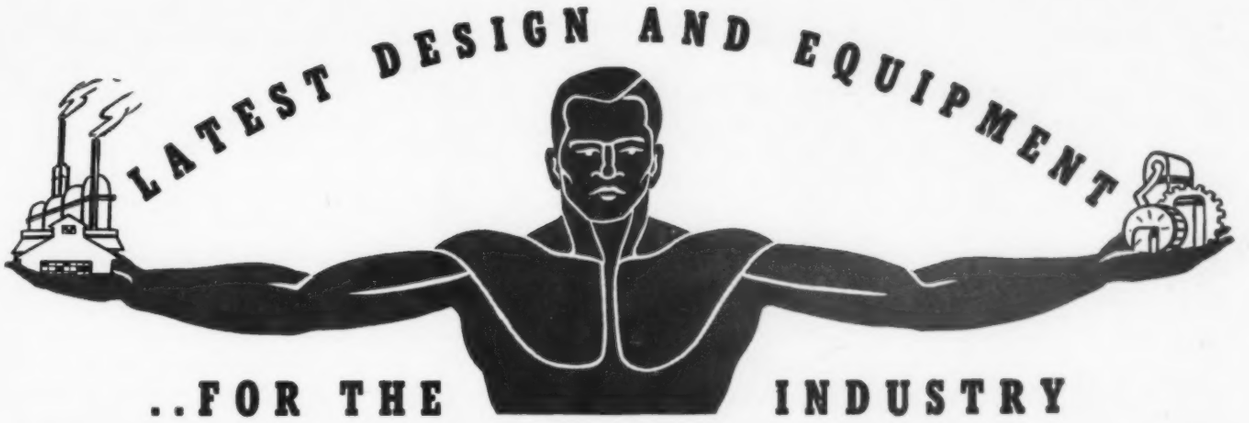


NEW PROVO PLANT TO START PRODUCTION IN MAY

▲ More than 8,000 men are now employed in construction of the tremendous $150,000,000 Geneva Works, near Provo, Utah, one of the nation's largest steel plants. Columbia Steel Company, subsidiary of United States Steel Corporation, is constructing the giant plant for Defense Plant Corporation. To help alleviate the housing shortage in the area, 10 barracks, housing 100 men each, have been built and 20 more units are now under construction. Restaurants and canteen facilities are in operation, with a seating capacity of 1600 at one time.

Geneva Works is scheduled to produce pig iron by next April. However, the first material increase in Utah pig iron production will occur as early as December of this year, when a second blast furnace, now being installed for Defense Plant Corporation at Columbia's Ironton Works, near Provo, will go into production. This furnace was recently shipped from Joliet, Ill., to Ironton, and is now being enlarged and modernized. It had been inoperative at Joliet for several years.

Officials of Columbia Steel Company said that the new construction at Geneva Works and development of the Geneva coal mine were well ahead of schedule. Actual production of steel is expected to commence in May, when the first open hearth furnace will be completed and lighted. Additional open hearth furnaces will be in operation shortly thereafter.

The plant's structural mill will be in operation by June, as will be the big slabbing mill, and steel plates for the nation's shipbuilding industry will be rolling off the plate mill by June.

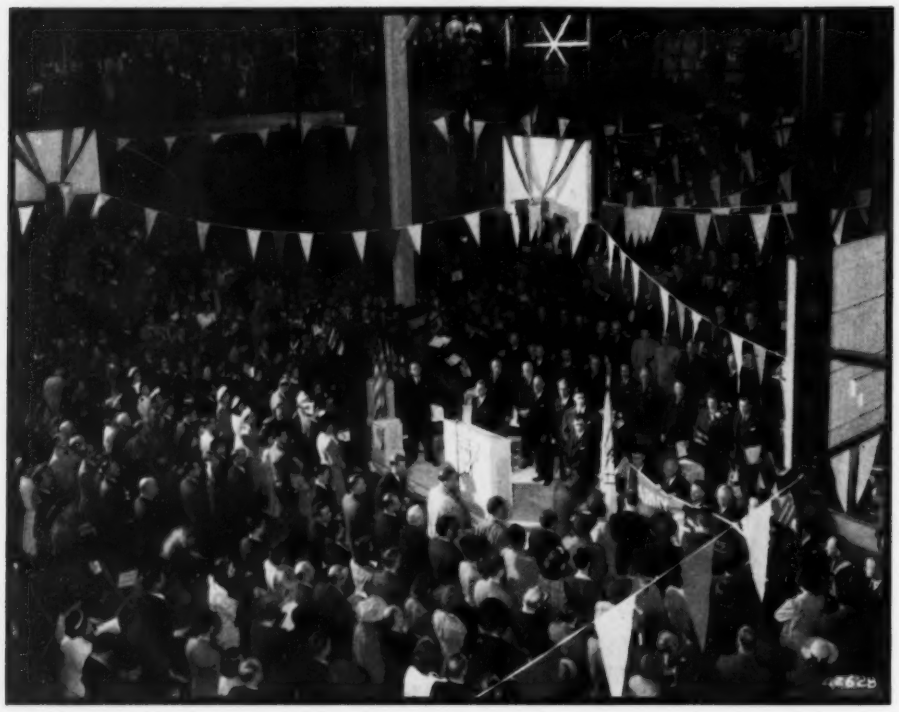
Already Geneva Works is beginning to take shape. Most of the 60 miles of spur track within the plant site has been completed. Foundations for the large blast furnaces, coke ovens, and other permanent installations are complete.

Geneva coal mine, which will supply coal to the new plant, will start production this month. Six and one-half miles of railroad, to haul coal from the mine to the plant, have been completed. This railroad, built through the wildest and roughest part of the Great Divide in the Wasatch Mountain Range, was completed in 60 days. Most of the road bed was cut out of solid formation of slate and rock. Movable camps, such as are being utilized in the building of the Alaskan Highway, were used in construction of the railroad. The vehicle highway, from Columbia, Utah, to Geneva mine in Forest Canyon, built under

The General Tours with New A. I. S. E. President

In a recent tour of industrial plants, Lieutenant-General William S. Knudsen, shown above with F. E. Flynn of Republic Steel Corporation, C. C. Rigsby of Packard Electric Division of General Motors, and J. B. Estabrook of Sunlight Electric Division of General Motors, inspected five plants in the Warren, Ohio, district. When interviewed, General Knudsen stated that Warren's war industries were in good shape, and that he was pleased with the attitude of the workers.

Armco Gets Joint Army-Navy E Award



Charles R. Hook, President of The American Rolling Mill Company, formally accepted the joint Army-Navy "E" award for excellence in production at Armco's Middletown and Hamilton, Ohio, Divisions on October 5. Token pins for Armco employees were also presented at the ceremony and all employees were given their Army-Navy production pin the following day.
Similar ceremonies were held on succeeding days at Armco's Butler, Pennsylvania, Ashland, Kentucky, and Zanesville, Ohio, plants — marking the first time that the coveted Army-Navy "E" production award has been won by all divisions of a steel company.

The Governor Lights New DPC Furnace at Republic

Ohio's governor, John W. Bricker, lights the new No. 1 blast furnace of Republic Steel Corporation at Youngstown. The furnace with a 1,100 ton capacity was built by the corporation for Defense Plant Corporation.
Left to right are John Pugh, general foreman, Blast Furnace Department, for 35 years an employee of Republic and its predecessor companies; R. L. Leventry, manager of Republic's Youngstown District; R. J. Wysor, Republic's president, and Governor Bricker.

similar conditions, has been finished. Facilities for increased production of iron ore at Iron Mountain, Utah, have also been completed.

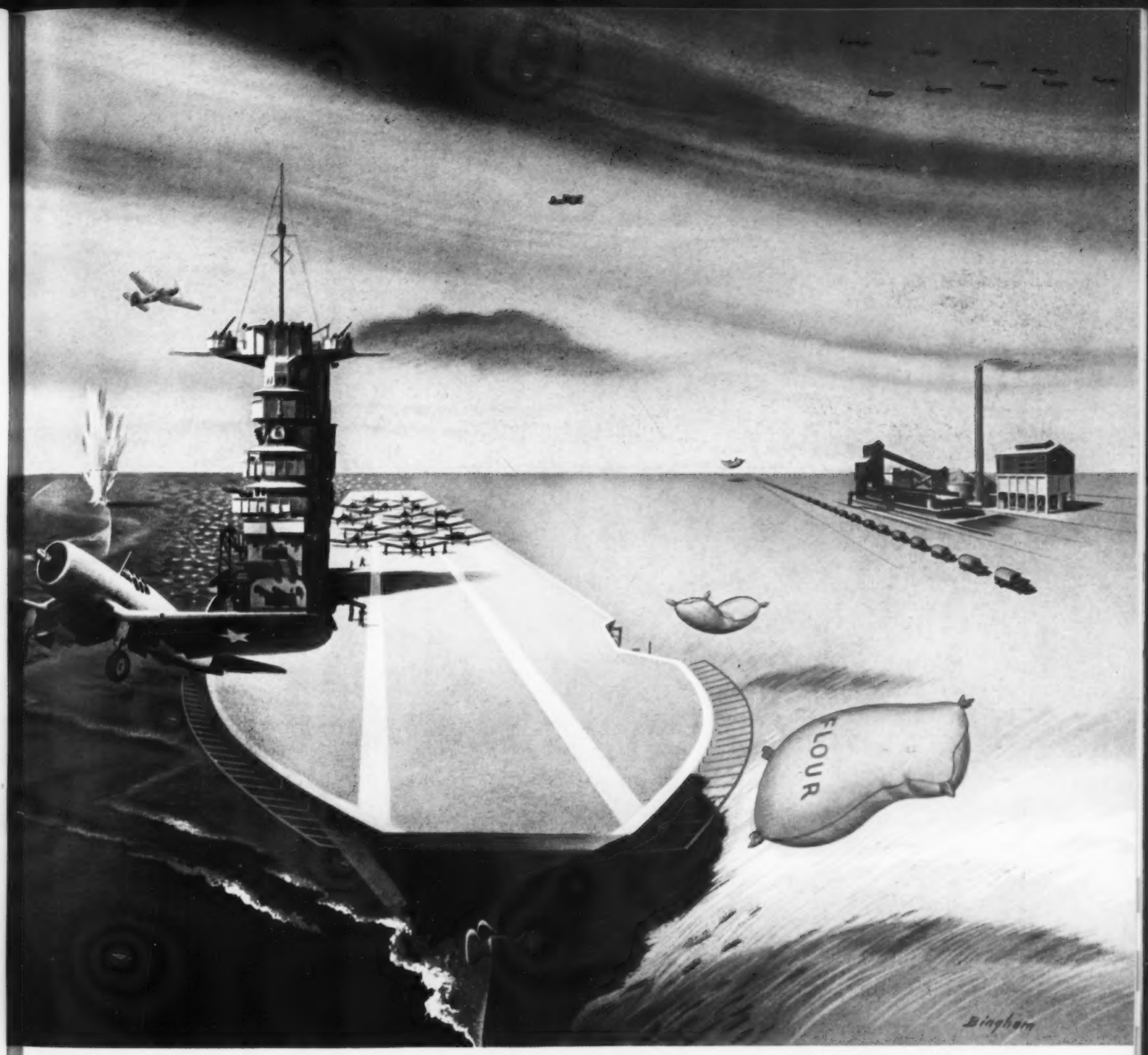
An unique problem has been the development of the water supply for the Geneva plant. There are two sources of water, one the metropolitan water district reservoir in the Wasatch Mountains, from which pipelines have been constructed, and the other the artesian wells on the plant site property. Because of the value of water to the community and the necessity of avoiding any waste of water for agricultural purposes, a complete recirculating system was constructed, with a reservoir covering 310 acres for collecting and storage purposes. This system will not only conserve water but will bring into the area for agricultural needs a larger quantity of water than existed before. The reservoir is now completed.

BARREL PUMP GIVES CONVENIENT OPERATION

▲ Trabon Engineering Corporation, Cleveland, Ohio, manufacturer of industrial lubricating equipment, has just introduced its new Series H Electric-Hydraulic barrel pumps.

These pumps are operated simply by plugging the extension cord into an electric outlet, thus permitting their use around a plant any time, and at any place an electric line is available. Due to this electric operation, these pumps are not only well adapted for service alongside a production line filling the bearings of various manufactured articles prior to their being shipped, — but also, are especially well suited for use by installation crews, setting up machinery in new plants, and by maintenance men working Sundays, holidays, etc., when compressed air, needed for operation of air driven pumps, usually is not available.

In addition to their wide field of usefulness, the manufacturer reports that the electric operation results in very low operating costs. The use of a non-compressible oil as a pumping agent, assures the discharging of the pumps' full rated capacity, at all times, regardless of whether the pressure head is high or low. These pumps are fully enclosed, and are sealed against the entrance of air . . . consequently, there is no opportunity for



An Army Travels on its Ammonium Sulfate

Did you think we were going to say "An army travels on its stomach?" Well, it's the same thing.

Many of the essential chemicals used by farmers in raising plants and animals are derived from coal.

One of the fundamental needs of the farm is nitrogen. It produces bigger yields and better qualities.

When the First World War started, the shortage of imported nitrogen made it difficult to get good fertilizers. Today, large supplies of nitrogen are obtained from ammonium sulfate recovered from the coal carbonized in Koppers coke ovens.

Koppers serves the farmer and the food industry in many other ways.

Fruits are often destroyed by diseases caused by fungi, or by dropping before ripe. Diseases of fruits are prevented by Koppers Flotation Sulfur. The premature dropping of unripe fruit is being prevented through the use of synthetic plant hormones made from naphthalene of which Koppers is a major producer.

Koppers built the first large American plant for recovery of ammonium thiocyanate, an essential raw material in the production of complex organic thiocyanates for insecticide manufacture.

Farmers control animal parasites with coal tar products . . . they get their products to market on roads built of coal tars . . . they prevent decay and destruction of wooden farm structures through the use of lumber pressure treated with Koppers creosote . . . they use Koppers American Hammered Piston Rings in many farm vehicles.—Koppers Co., Pittsburgh, Pa.

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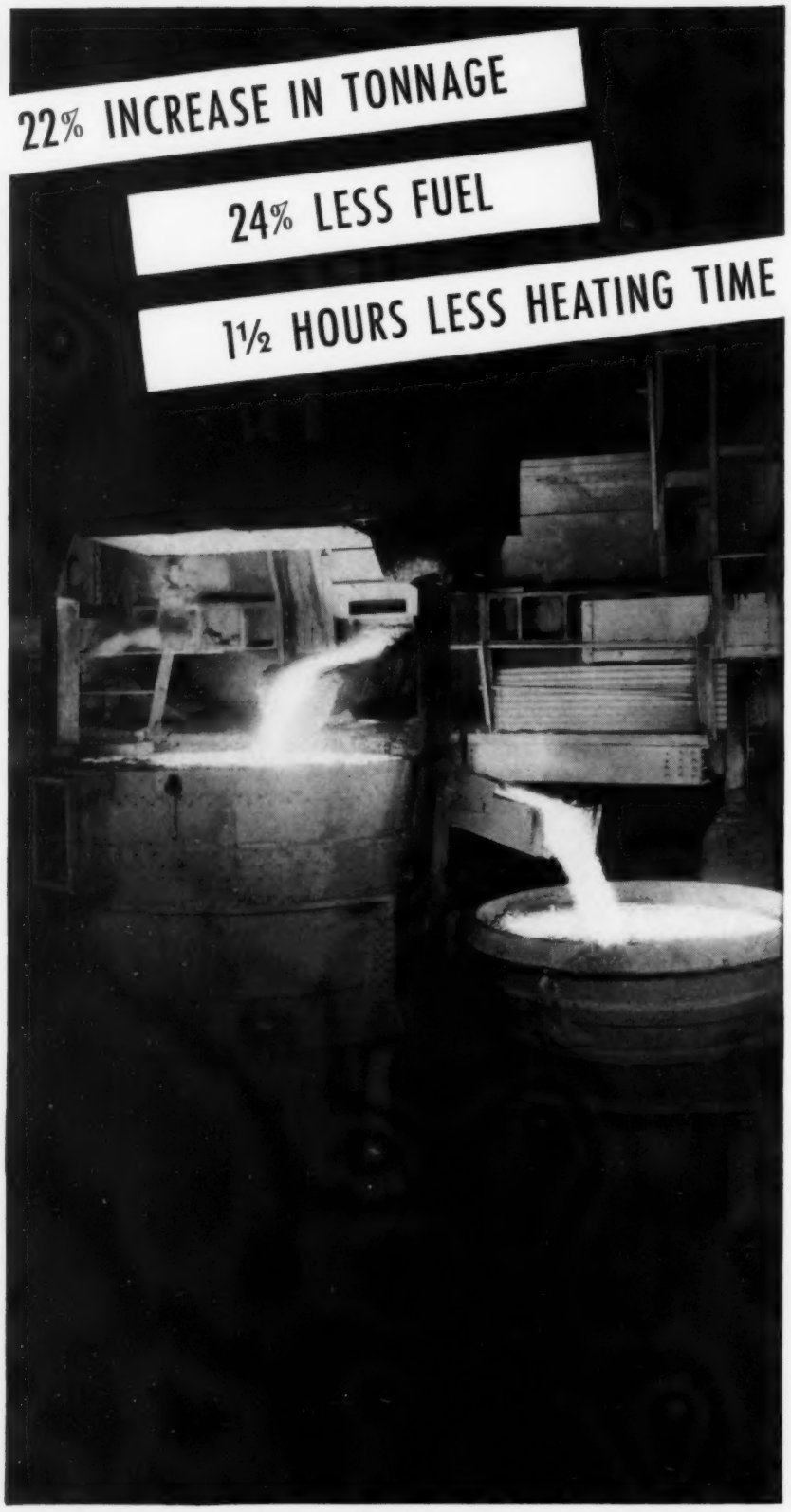

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THESE are some of the *unusual* results steel makers are obtaining when open hearth furnaces are designed especially for automatic combustion control.

The average increase in tonnage, of course, is not that high, but often runs from 5% to 10%.

The steel industry is now striving for an overall increase in tonnage of 10%. Why not make a careful investigation of just what increase you can get from automatic combustion control on *all* your furnaces—open hearth, blast furnaces, soaking pits, billet heaters, etc.

Better, faster, more uniform heating moves steel all along the line at greater speeds. There's less spoilage, fewer defects and a more uniform product. All this is obtained with considerably less fuel consumption per ton.

Hagan control can be installed on old or new furnaces. It requires no increase in available space and offers one of the quickest ways to get substantial increases in tonnage.

Let us prove this in your own plant by sending a Hagan Combustion Specialist now. A *new* pair of eyes can often see possible improvements not obvious to your own staff.

HAGAN OPEN HEARTH FURNACE CONTROL PROVIDES:

1. **Fuel input control,** for regulation of heat input of the fuels burned.
2. **Fuel-air ratio control,** to admit air in the exact ratio each fuel requires for best efficiency.
3. **Furnace pressure control,** by regulation of stack damper.
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HAGAN *Automatic* COMBUSTION CONTROL

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dirt, grit, or moisture to gain entrance to the pump in an air stream, with resulting wear, rusting, etc. The pumps are self-lubricating, and require little servicing.

The pump, complete with motor, hydraulic cylinder, etc., is mounted rigidly on a flanged head. The flange fits snugly over a standard 55 gal-400 lb drum permitting oil, or light medium or heavy grease to be pumped from the original shipping container without rehandling, — and a lifting bail is provided permitting the unit to be transferred easily from one drum to another, with a hand hoist or lifting bar.

These pumps, see illustration above, are operated with a ½ hp motor direct connected to the hydraulic pumping unit which is located in the bottom of the hydraulic reservoir. Oil from the hydraulic reservoir is pumped through a reversing mechanism which operates the pumping piston. This piston is double-acting. Consequently the pump discharges lubricant on both the up and down strokes, maintaining a constant, continuous discharge.

The pumping action is entirely automatic. No springs or cams are

This electric-hydraulic barrel pump may be used at any place where an electric outlet is available.

U. S. Steel Board Holds First Meeting in Chicago

The Board of Directors of the United States Steel Corporation as they arrived in Chicago September 23 for the first meeting of the Board held outside of New York City in the history of the Corporation. Following this meeting, the Directors visited South Chicago, Illinois, and Gary, Indiana, operations of subsidiary companies. Left to right: Philip R. Clarke; Robert C. Stanley; George A. Sloan; William A. Irvin; Benjamin F. Fairless, President; Irving S. Olds, Chairman; Enders M. Voorhees, Chairman of Finance Committee; Thomas W. Lamont; William J. Filbert; Leon Fraser and Sewell L. Avery.

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We're Backing Up Our Fighting Men
EVERYONE IN OUR ORGANIZATION
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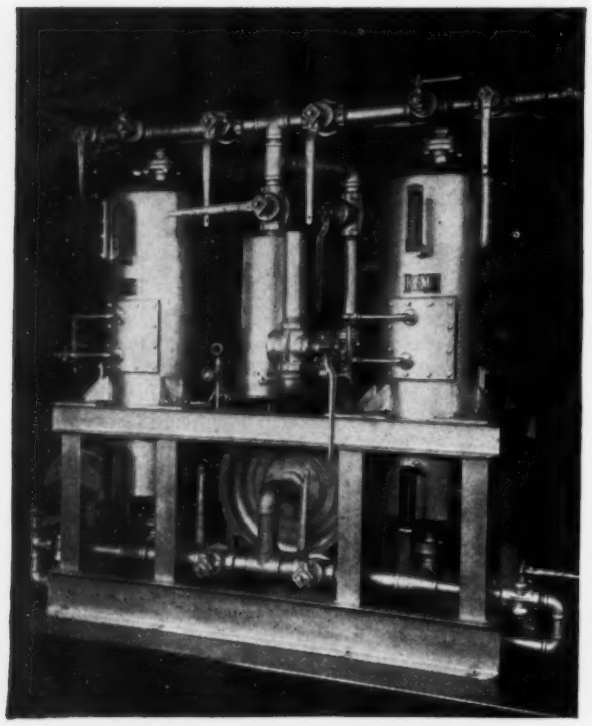
PENNSYLVANIA TRANSFORMER COMPANY

Mr. Samuel Horelick, President of Pennsylvania Transformer Company, addressing employees upon the occasion of the 10% flag presentation program of this company. Over 300 workers attended this rally, with Chaplain Elvin Shaffstall of the United States Army as the guest speaker. W. E. Kerr, Vice President of the company also gave a brief talk.

used, and there is nothing to wear. The pistons cannot stop on dead center. The pumps encounter no sticking and, since three sizes of pumping units and two sizes of piston reversing mechanisms are available, the pumps can be furnished in six different discharge capacity and pressure combinations to meet different service requirements.

The operation of the pump is controlled usually with the automatic pressure switch. When the grease outlet is opened the reduced pressure in the line trips the switch immediately starting the motor. When the grease outlet is closed, the pressure built up in the line again trips the switch, shutting off the motor, and stopping the pumping action. A fully descriptive engineering bulletin, prices, etc., can be secured by writing Trabon Engineering Corporation, 1814 East 40th Street, Cleveland, Ohio.



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KEMP SILICA GEL DEHYDRATORS guarantee the *exact* degree of dryness you need in *your* annealing atmospheres.

Designed by gas equipment engineers; and proven by an impressive record of dependable and economical operation in plants demanding constant and exact drying of annealing atmospheres.

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Capacities: 10 to 100,000 c.f.m.
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DROP IN TIN PLATE CLOSES WEIRTON PLANT

▲ The Steubenville Plant of the Weirton Steel Company has been shut down as a result of a drastic reduction in the manufacture of tin plate products on order of the War Production Board, it was announced recently by E. T. Weir, chairman of National Steel Corporation, of which the Weirton Steel Company is a subsidiary.

Under the War Production Board order, Mr. Weir said, the operations of the tin plate industry will not be over 25 per cent of capacity in the fourth quarter of this year.

"This very drastic reduction in tin plate operations," Mr. Weir said, "will no doubt have a deteriorating effect on the organizations of the tin plate mills of the industry."

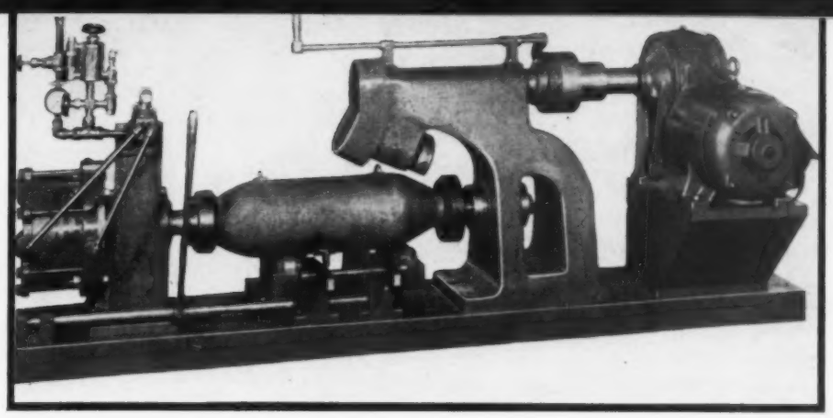
The Steubenville Plant, which normally has more than 1,000 employees on its payroll, is devoted exclusively to the production of tin plate. Tin plate is only one of a group of tin mill products, all of which are equally affected by the War Production Board order reducing operatings.

Since the Steubenville Plant cannot be operated to produce its one grade of material on a greatly restricted basis, Mr. Weir said, all operations temporarily will be conducted at the Company's other tin mill in Weirton which manufactures the full line of tin mill products, including electrolytic tin plate.

As many Steubenville employees as possible, including all male employees, are being offered employment at Weirton. A large number of these employees already have been placed in positions at Weirton and the remainder will be placed as rapidly as conditions permit. The Steubenville Plant will be maintained in perfect physical condition, Mr. Weir said.

MACHINE MARKS DATA ON SURFACE OF BOMBS

▲ A machine has been developed for marking all required data on the conical tail surface of bombs by the Jas. H. Matthews and Company. Adaptable for installation in production lines, it completes the marking noiselessly. Machine features provide for variations and irregularities in bomb surface to be marked, to assure complete and legible impressions. The machine is semi-automatic, made in



A roller die with interchangeable type progressive marks required data on bomb surface.

various sizes for marking 100 lb to 1,000 lb bombs. Usually installed between sand-blasting and hydro-static tests.

To operate, bomb is rolled into the machine in the position illustrated, resting on the cradle rolls. It is held in position by a pneumatic thrust chuck at the nose . . . and by a rotating thrust bearing at the tail. To mark bombs . . . a single revolution clutch is tripped by a hand lever. A roller die with interchangeable type rotates the bomb and progressively marks the required data, in one line of ¼ in. characters on the conical tail surface.

The bomb is then raised from the cradle rolls and allowed to roll from the machine.

TRUCK MAINTENANCE DATA AVAILABLE

▲ Industrial truck maintenance is a mythical operation in many plants. Because of the ruggedness of this equipment, in many cases it is given only a hasty inspection; in fact, frequently, none at all; and is but rarely lubricated. Coupled with the fact that some operators have little regard for careful operation this results in costly breakdowns. Trucks are forced, by going from low to high speed with heavy loads; they are plugged in reverse to stop; they are rammed, and skidded around corners; and, in general subjected to treatment, which even their sturdy constitutions were not intended to withstand.

The industrial truck can pay dividends only so long as it is kept in operation; and the investment of regular inspection and lubrication, under competent management, is one of the best you can make.

In keeping with the principles of good truck maintenance, A. E. Dorod, assistant chief engineer, Baker-Raulang Company has prepared a thorough study of this subject and complete information may be obtained by addressing the company.

ANOTHER "E" FOR FARREL

▲ The Navy Board for Production Awards has announced that a second All-Navy "E" Award has been won by Farrel-Birmingham Company, Inc. of Ansonia, Connecticut. Each of the company's three plants — at Ansonia and Derby, Connecticut, and Buffalo, New York — have earned the privilege of flying the Navy "E" burgee with a white star added.

The white star carries a special and

BETTER RESULTS IN FURNACE OPERATION with HAYS INSTRUMENTS

SUPERSENSITIVE DRAFT RECORDERS SERIES "OT" You can make sure of BALANCED Draft Conditions in Open Hearths, Soaking Pits, Annealing Furnaces and Slag Mills by installing Hays Series OT Recorders.

These instruments give a correct indication of furnace atmospheres and a permanent record of pressures and drafts at vital points as guides for most effective operation.

Write for descriptive bulletin.

PATENTS PENDING. This gage is calibrated in terms of air and gas flow—but may be used for any two flows for which the instrument is calibrated.

HAYS VISIO-RATIO GAGE

3 INSTRUMENTS IN 1 . . . 1. Air-Flow Indicator . . . 2. Fuel-Flow Indicator . . . 3. Ratio Indicator. Shows at a glance the exact ratio existing between flow of gas or flow of oil or other measurable fluid: pressure, draft, suction, temperature (up to 1000° F.) speed in R.P.M. or inches per minute, position, level and others.

This newest Hays instrument is a guide to higher manufacturing efficiency, increased production, better products and lower costs. It shows relations at a glance and eliminates the necessity of making calculations to determine excess or deficiency.

If you will write us, stating the conditions, we will tell you exactly how the Hays Visio-Ratio Gage can be applied to your problem.

The HAYS CORPORATION
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

added significance, according to Admiral H. A. Wiley, USN (Ret.), Chairman of the Navy Board for Production Awards. He highlighted this point in a letter of congratulation to N. W. Pickering, president of Farrel-Birmingham Company.

Farrel-Birmingham Company manufactures gear drives for ships of the U. S. Navy and U. S. Maritime Commission, besides heavy machinery for use in the war production of steel mills, non-ferrous rolling mills and the rubber, plastics, paper and sugar industries.

NEW LITERATURE

▲ At a time when a great many people are asking questions about dependable pyrometers for war-industry use, Leeds & Northrup have just reissued — in strictly up-to-date form — their catalog on Micromax Thermocouple Pyrometers.

In 56 well-illustrated pages, this book trys to cut correspondence and to give war-time pyrometer users first hand the information they want about available instruments — indicators, recorders and controllers — and about the thermocouples and accessories which are used with them.

If, as a result of war-time conversion, you're a new or prospective user of balance-type (potentiometer) pyrometers, you'll be particularly interested in the concise but comprehensive description this book contains of how the basically-sound balance method is applied to the measurement and control of thermocouple temperatures.

In case you happen to have a copy of last year's edition, it should be pointed out that the present book differs from the 1941 edition only in minor detail.

But, as compared with the 1939 and previous editions — many copies of which are still in use — the present book is extensively revised. An automatically-balanced Micromax Indicator and the Model C Controller (non-indicating) for flush mounting have been added. The section on thermocouples has been expanded. Automatic control is outlined more fully than in previous editions.

To get a copy, ask Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia, Pennsylvania, for Catalog N-33A, Micromax Thermocouple Pyrometers.

▲ The Allis-Chalmers Mfg. Company, Milwaukee, Wisconsin, has just released a new motor bulletin, designed to give all the facts necessary for quickly choosing correct motors for wartime applications, thereby fully utilizing electric motor power and conserving vital war materials.

In the new book, Bulletin B6052-C, compact, simplified charts permit the reader to determine at a glance all electrical and mechanical characteristics of the motor types designed for the specific application in which he is interested. For each design and application relationship, rating, duty, torques, starting current, efficiency and slip are indicated — for squirrel-cage, wound rotor, direct current and synchronous motors.

In addition, construction features of various Allis-Chalmers Lo-Maintenance Motors are completely described and numerous typical applications are illustrated. The compact motor manual also includes handy speed-torque curves, as well as discussions of several engineering phases of motor application, such as the recommended use of higher speed

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Arktite

CIRCUIT BREAKING

Plugs and Receptacles

1. Provide safe connections for all electrical machinery.

2. Exclusive *Arktite* circuit breaking construction. Can be pulled under full load.

3. Positive grounding circuit.

- Style I grounded through plug shell and receptacle housing.
- Style II has extra contacts for the grounded safety circuit. *This should always be used where corrosive conditions exist.*

4. The complete line meets all installation requirements.

- Suitable Condulet housings for every application.
- 20 to 400 Amperes, 600 Volts AC.
- All standard wiring systems. Style I, 2 pole to 5 pole. Style II, 2 wire 3 pole to 4 wire 5 pole.

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CROUSE-HINDS COMPANY OF CANADA, LTD., *Main Office and Plant:* TORONTO, ONT.

motors and adjustable speed. Dimension ratings and price lists are likewise included.

Copies of Bulletin B6052-C are now available on request.

▲ "A Guide to Better Bearing Lubrication" distributed by S-K-F Industries, Inc., Philadelphia manufacturers of ball and roller bearings, fills a vital need in all industries. Thirty-two pages are filled with designs, formulae, and graphs which explain the highly technical text. Subjects treated include the functions of lubrication, oil lubrication, recommended viscosities, oil supply systems, oil bath, circulating systems, spray or mist lubrication, wick feed, oil with compressed air, grease lubrication, how grease lubricates, ABEC grease standard, operating conditions, greasing intervals, grease supply systems, housing with grease fittings, housings without grease fittings, grease chamber lubrication, comparative advantages of oil and grease, high-temperature applications, minimum friction applications, protection against moisture, protection of idle machinery, cleaning. Also this company has available a new reference volume which contains formulae, designs, data tabulations and illustrations. Its enlarged scope covers bearing applications for auxiliary equipment, cranes, drives and roll-neck bearing design maintenance and lubrication.

▲ The Vaughn Machinery Company, Cuyahoga Falls, Ohio, manufacturers of cold drawing equipment, recently issued a twelve page, well illustrated, bulletin. This brochure indicates the broad type of equipment manufactured by this company and contains many features of interest to the users of cold drawing equipment.

▲ A new copy of the catalog, a quick reference listing of all Colt Electrical Products, has just been published. Included are complete listings of all Type A, C and D Safety Switches and Industrial Control Equipment.

Copies will be sent on request. Address: "Department Adv., Colt's Patent Fire Arms Mfg. Company, Hartford, Connecticut."

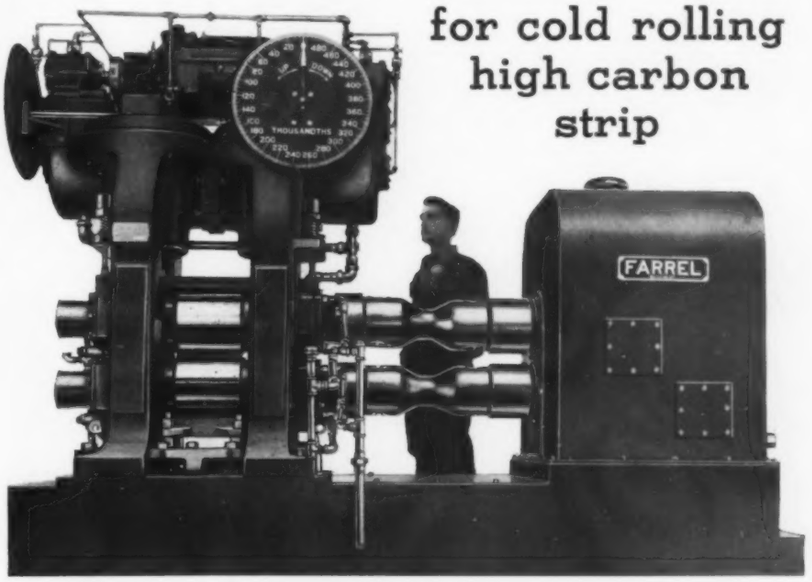
▲ Chain Belt Company has issued a new illustrated folder describing its Rex Spray Nozzles. The illustrations of this ingenious device in the folder show various uses which range all the way from cooling fruit in packing plants and cleaning trolley busses in garages to washing logs in lumber mills or descaling sheets and plates in steel mills. In the steel industry, Rex Spray Nozzles have proved their outstanding ability in cooling rolls and descaling billets and plates.

The nozzle itself is described as a non-clogging device which throws a flat fan-like, hard-hitting spray with such force that it removes dirt and grit from the most irregular surfaces. The high velocity spray is so concentrated that it produces an extremely thin line of impact which amounts to a sharp cutting action. The device was originally developed for cleaning traveling water screens and because of its unusual effectiveness has since been adapted for many other purposes. The folder is known as Bulletin No. 409 and will be sent on request to anyone interested.

NEW *HIGH-SPEED*

HIGH-PRECISION FARREL MILL

for cold rolling high carbon strip



Ruggedly built for continuous, high-speed operation, this new Farrel 10″ x 10″ Two-High Rolling Mill is also specially designed to insure high accuracy and close control of gauge in cold rolling high carbon steel strip.

A feature is the built-in screwdown, which is extremely high-powered to adjust the gauge on high carbon steel under full load. This screwdown provides ease of manipulation and facilitates setting the rolls with extreme accuracy. Duplex control is provided for operating either screw independently or synchronizing both screws through magnetic clutches.

The rolls are forged alloy steel, heat treated and hardened. They are carried in precision-type, flood-lubricated sleeve bearings and are connected to the pinion stand with universal spindles. The mill housings are of cast steel of heavy section for maximum strength and rigidity.

The mill is driven by a variable speed, reversing motor through a combined reduction gear unit and pinion stand, with Farrel-Sykes continuous tooth herringbone gears and mill pinions mounted in anti-friction bearings in a welded steel housing.

Farrel Rolling Mills are designed and built to fit individual conditions of operation, and experienced engineers are available for consultation to assist in working out applications to special production requirements.

FARREL

FARREL-BIRMINGHAM COMPANY, Inc.
ANSONIA, CONN.
New York • Buffalo • Pittsburgh • Akron • Chicago • Los Angeles

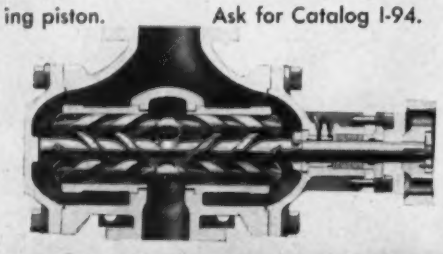
IMO MOVE OIL

for High Pressure

LUBE OIL

This De Laval-IMO

rotary displacement pump, directly connected to a motor running at 1450 r.p.m., delivers oil against a pressure of 330 lbs. per sq. in. to the lubricating system of the vertical thrust bearing of a large hydraulic turbine. The pump end is submerged in the oil sump. There are no valves, no gears and no pump bearings. The flow is without pulsation, as from a steadily advancing piston. Ask for Catalog I-94.



IMO PUMP DIVISION
of the De Laval Steam Turbine Company, Trenton, N. J.

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MARKING DEVICES
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Plant Managers! Superintendents! Purchasing Agents! Production and Plant Engineers! Here's a book that will give you the answers to your marking problems. It contains hundreds of illustrations, with concise descriptions of Marking Devices for every Industrial Marking application. Yours for the asking . . . request a copy on your letterhead today!

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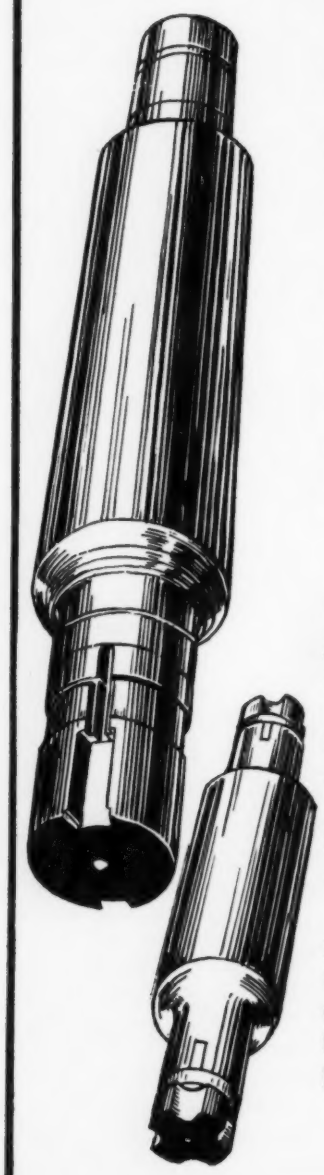
NATIONAL ROLLS



Unending Search for Roll Perfection

OFTEN the variables in metal, alloys, furnace, casting pit and even temperatures will cause two rolls of the same specification to perform in different range.

With accruing success, we have located most of these variations and applied neutralizing method to the stage where we believe NATIONAL ROLLS—both plain iron-chill and grain—are as uniform in performance as modern processing can produce.

A NATIONAL ROLL is made to fit a specific rolling purpose—thus much of the process is specialized to the particular purpose intended.

THE NATIONAL ROLL & FOUNDRY CO.
Rolls & Rolling Mill Equipment
AVONMORE, PA.

ITEMS OF INTEREST

W. Louis Bunting and **William S. Jasinsky** have been appointed superintendent and assistant superintendent of plate mills, respectively, for Lukens Steel Company, Coatesville, Pennsylvania.

Mr. Bunting first entered the employ of Lukens Steel Company as a water tender in 1909. From that time on, his record has been one of steady promotions in many departments, giving him a well-rounded knowledge of steel processes.

During 33 years with the company, Mr. Bunting worked successively as a furnace recorder, millwright, clerk, pit craneman, pit helper, tableman, screwman, and roller. In 1933, he supervised the rolling on the company's five plate mills.

In 1937, he became superintendent of the 140 in.-206 in. mills and held this post until his recent promotion.

Mr. Jasinsky's rise with Lukens parallels that of Mr. Bunting's. He was first employed by the company as a layer-out in 1917. Except for one month he has been with Lukens successively as a finisher, foreman, general foreman of all plate mills, and superintendent of the 84 in. and 112 in. mills, until his recent appointment to his present post.

D. L. (Doc) Immel has been promoted to assistant plant superintendent at the Copperweld Steel Company's Warren, Ohio, plant. Mr. Immel has had many other positions of responsibility with various other steel companies.

Mr. Immel came to Copperweld from Republic Steel Corporation, Cleveland, Ohio, where he was blooming mill superintendent. Prior to that he had served as superintendent of mills in the Canton-Massillon district of Republic and its predecessors, Central Steel Company and Central Alloy Steel Corporation.

D. L. IMMEL

BUD SCOTT PHOTO

W. S. JASINSKY and W. L. BUNTING

H. L. Watson, since 1934 executive vice-president and director of the De Laval Steam Turbine Company, Trenton, New Jersey, has been elected to the Presidency of that company, succeeding Francis J. Arend, who died, August 24, 1942. From 1913 to 1934, Mr. Watson was general sales manager. He graduated from Rose Polytechnic Institute, Terre Haute, Indiana, in 1905 and served as erecting engineer and later as sales engineer, specializing in steam turbine work, with the Allis-Chalmers Company until he entered the employ of the De Laval Company.

Lawrence E. Riddle, general superintendent, Isabella Furnaces; and superintendent, blast furnaces, Duquesne Works, Carnegie-Illinois Steel Corporation, was honored recently upon the completion of 50 years' service with this U. S. Steel subsdidiary.

Mr. Riddle, a Pittsburgher, entered the employ of the Carnegie Steel Company on October 1, 1892, as a sample boy in the laboratory of Isabella Furnaces. From 1893 until 1909, when he became assistant superintendent of these Furnaces, he worked at jobs ranging from assistant chemist to general foreman. On November 1, 1911, he was made superintendent of Isabella Furnaces and on January 1, 1913, the superintendency of the Lucy Furnaces of Carnegie Steel Company was added to his responsibilities.

From 1914 to 1926 he served as general superintendent, City Blast Furnace Plants. In 1926 he took on the additional duties of superintendent, Blast Furnaces, Duquesne Works, which positions he held until 1937. At that time when the City blast furnace plants became inoperative he was made general superintendent, Isabella furnaces, and superintendent, blast furnaces, Duquesne Works, which joint responsibility he has held up to the present time.

Robert P. Freehafer who has been assistant purchasing agent of the Carpenter Steel Company, has now been advanced to purchasing agent of the same company.

Bradford C. Colcord, formerly general superintendent of the National Works of the National Tube Company at McKeesport, Pennsylvania, has been promoted to assistant vice president of operations, with headquarters at the general offices in Pittsburgh.

Ralph M. Overton, who has been assistant general superintendent of National Works, is advanced to general superintendent of the plant.

O. P. Adams, formerly superintendent of maintenance, National Works, will become assistant general superintendent.

Captain C. A. Trexel and **A. Amirikian,** director of planning and design, and design engineer, respectively, Bureau of Yards and Docks, Navy Department, Washington, D. C., were, the recipients of the $13,700 Grand Award in the nation-wide 2½-year $200,000 scientific welding study program sponsored by The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.

The 2½-year welding study, known as the "$200,000 Industrial Progress Award Program," brought forth reports of welding progress prepared by executives, engineers, designers, architects, production officials and others throughout the industrial field. The study indicated a possibility of tremendous savings in costs and man hours for production of products by arc welding for both war and peace.

Thomas D. Jolly, chief engineer and director of purchases, and **M. M. Anderson,** personnel manager and director of labor relations of the Aluminum Company of America, have been elected vice presidents of the company.

Henry A. Roemer, Jr., formerly manager of sales of steel and wire products, Pittsburgh Steel Company, is advanced to assistant general manager of sales, and **Norman F. Melville,** formerly assistant manager of sales of steel and wire products, has been made manager of sales of that department.

Merrill Cox has been appointed sales manager of Arthur G. McKee & Company's iron and steel division. Mr. Cox has held the position of assistant chief engineer in this division and previously had served both as service and sales engineer.

CORRECTION

On page 56, second column, fourth paragraph, the statement "Abrasion loss not exceeding 40 milligrams, *should read* "Abrasion loss not exceeding 4 milligrams".

STATEMENT OF OWNERSHIP, MANAGEMENT, ETC., OF

IRON AND STEEL ENGINEER

(Required by Act of Congress of August 24, 1912)

Name of Publication: *Iron and Steel Engineer*, published monthly at Pittsburgh, Pa. (Report of October 1, 1942.)

Editor: Brent Wiley, Empire Building, Pittsburgh, Pa.

Business Manager: James D. Kelly, Empire Building, Pittsburgh, Pa.

Names and addresses of stockholders holding 1 per cent or more of total amount of stock: None.

BOARD OF DIRECTORS

1942

President, Thomas E. Hughes, *Superintendent of Maintenance*, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.

First Vice-President, Frank E. Flynn, *District Manager*, Republic Steel Corporation, Warren, Ohio.

Second Vice-President, C. L. McGranahan, *Assistant General Superintendent*, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

Treasurer, L. F. Coffin, *Superintendent Mechanical Department*, Bethlehem Steel Company, Sparrows Point, Maryland.

Secretary, J. L. Miller, *Assistant Chief Combustion Engineer*, Republic Steel Corporation, Cleveland, Ohio.

Past Presidents: William A. Perry, *Superintendent Electrical and Power Departments*, Inland Steel Company, Indiana Harbor, Indiana.

Julius A. Clauss, *Chief Engineer*, Great Lakes Steel Corporation, Ecorse, Michigan.

Honorary Directors: James Farrington, *Electrical Superintendent*, Wheeling Steel Corporation, Steubenville, Ohio.

A. C. Cummins, *General Superintendent*, Youngstown District, Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

Walter H. Burr, *Electrical Superintendent*, Lukens Steel Company, Coatesville, Pennsylvania.

Director-at-Large, Freeman H. Dyke, *Superintendent, Blooming, Bar and Hot Strip Mills*, Wheeling Steel Corporation, Steubenville, Ohio.

Directors: H. R. Middlebrook, *Assistant Division Superintendent, Power and Fuel*, Carnegie-Illinois Steel Corporation, Gary, Indiana.

A. J. Fisher, *Fuel Engineer*, Bethlehem Steel Company, Sparrows Point, Maryland.

H. T. Watts, *Combustion Engineer*, Republic Steel Corporation, Gadsden, Alabama.

T. B. McElray, *Superintendent, Light and Power*, Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

A. J. F. MacQueen, *Superintendent of Maintenance*, Rotary Electric Steel Company, Detroit, Michigan.

J. D. Jones, *Chief Engineer*, Youngstown Sheet and Tube Company, Youngstown, Ohio.

L. F. Reinartz, *Works Manager*, American Rolling Mill Company, Middletown, Ohio.

A. W. Duncan, *Electrical Superintendent*, Weirton Steel Company, Weirton, West Virginia.

H. W. Neblett, *Development and New Design Engineer*, Inland Steel Company, East Chicago, Indiana.

Managing Director, Brent Wiley, Empire Building, Pittsburgh, Pennsylvania.

Known bondholders, mortgages and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages or other securities: None.

JAMES D. KELLY, Business Manager.

Sworn to and subscribed before me this twenty-eighth day of September, 1942.

G. WILLIAM JONES, JR., Notary Public

(My commission expires February 9, 1943.)

NATIONAL ROLLS

HEAVY IRON CASTINGS CAPACITY AVAILABLE

(Air Furnace or Cupola Iron)
(Up to 70,000 Pounds)

● We have capacity for heavy iron castings and can make good delivery.

Machining capacity on 8 ft. by 36 ft. and 7 ft. by 22 ft. planers.

We invite your inquiries, which will receive our immediate attention.

THE NATIONAL ROLL & FOUNDRY CO.
MANUFACTURERS OF
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BAIRD WATER COOLED STANDINGS · HEAVY IRON AND STEEL CASTINGS
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Keep your Rod, Merchant and Bar Mills
rolling longer between roll changes . . .

for all stands

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PROCESS ALLOY IRON BASE ROLLS

Other Mackintosh-Hemphill Products:

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Levellers

Improved Johnston Patented Corrugated

Cinder Pots and Supports

Iron-Steel Castings

NEW Abramsen Straightener

Pinions

Special Equipment

Heavy Duty Engine Lathes

You will get greater production between roll changes with all stands of your rod, merchant and bar mills equipped with "Techni" Process alloy iron base rolls, for they roll more tons for each roll dressing. "Techni" Process Rolls have greater strength, excellent finish, unusual wearing qualities, resistance to slippage and fire cracking. Mackintosh-Hemphill and "Techni" Process will assist you in getting the most production from your mills.

Since 1803—Pioneers, Engineers and Builders

MACKINTOSH-HEMPHILL COMPANY . . . Pittsburgh and Midland, Pa.

The Rolls with the Red Wabblers

They Roll More Tons Per Roll-Dressing

P-G

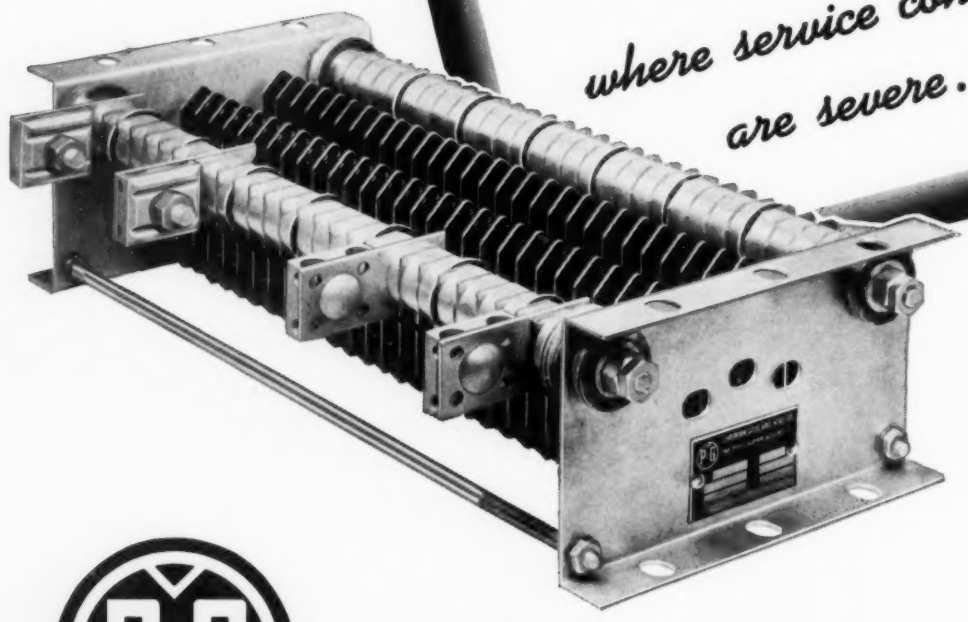
Steel Grid Resistors

PROTECT VITAL ELECTRICAL EQUIPMENT!

In heavy industry generally and especially in...

STEEL MILLS

where service conditions are severe...



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• ESTABLISHED 1892 •

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EASY ON THE CRANE ...easy on the Operator!

Graduated dynamic braking and accurate inching control makes crane operation easier . . . safer!

Here's control that speeds up hoisting operations—yet reduces stress and strain on both crane and operator!

Faster light-hook lowering speed saves time between loads, yet without excessive speeds when lowering heavy loads—and without complications and hazards of load relays. At the same time, graduated dynamic braking, which accomplishes most of the deceleration before the magnetic brake sets, reduces stresses on the crane and gives smoother braking action.

Inching control is made more accurate—load handling is made easier, quicker, safer. Write today for bulletin DD-9600 containing full details. Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., Dept. 7-N.

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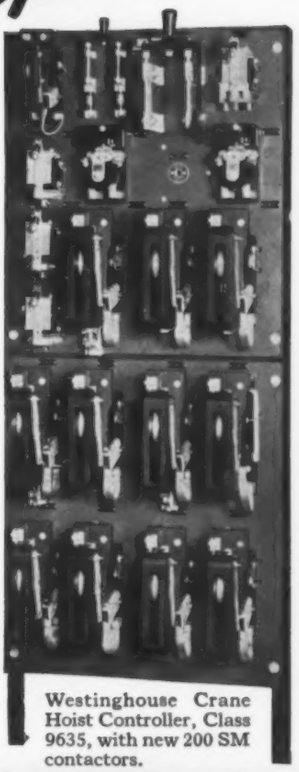
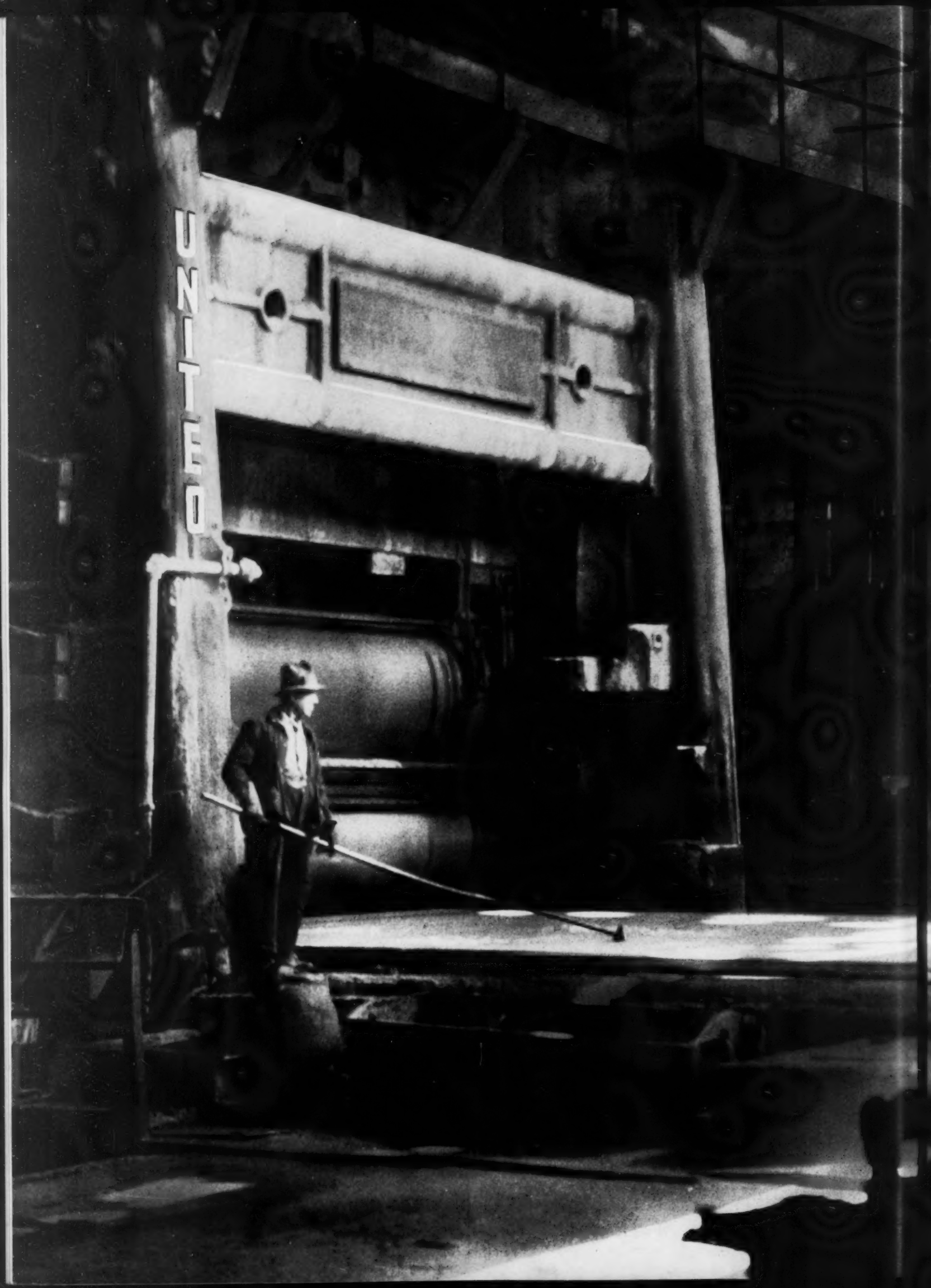


Westinghouse Crane Hoist Controller, Class 9635, with new 200 SM contactors.

Westinghouse D. C. CRANE CONTROLLERS

WESTINGHOUSE ELECTRIC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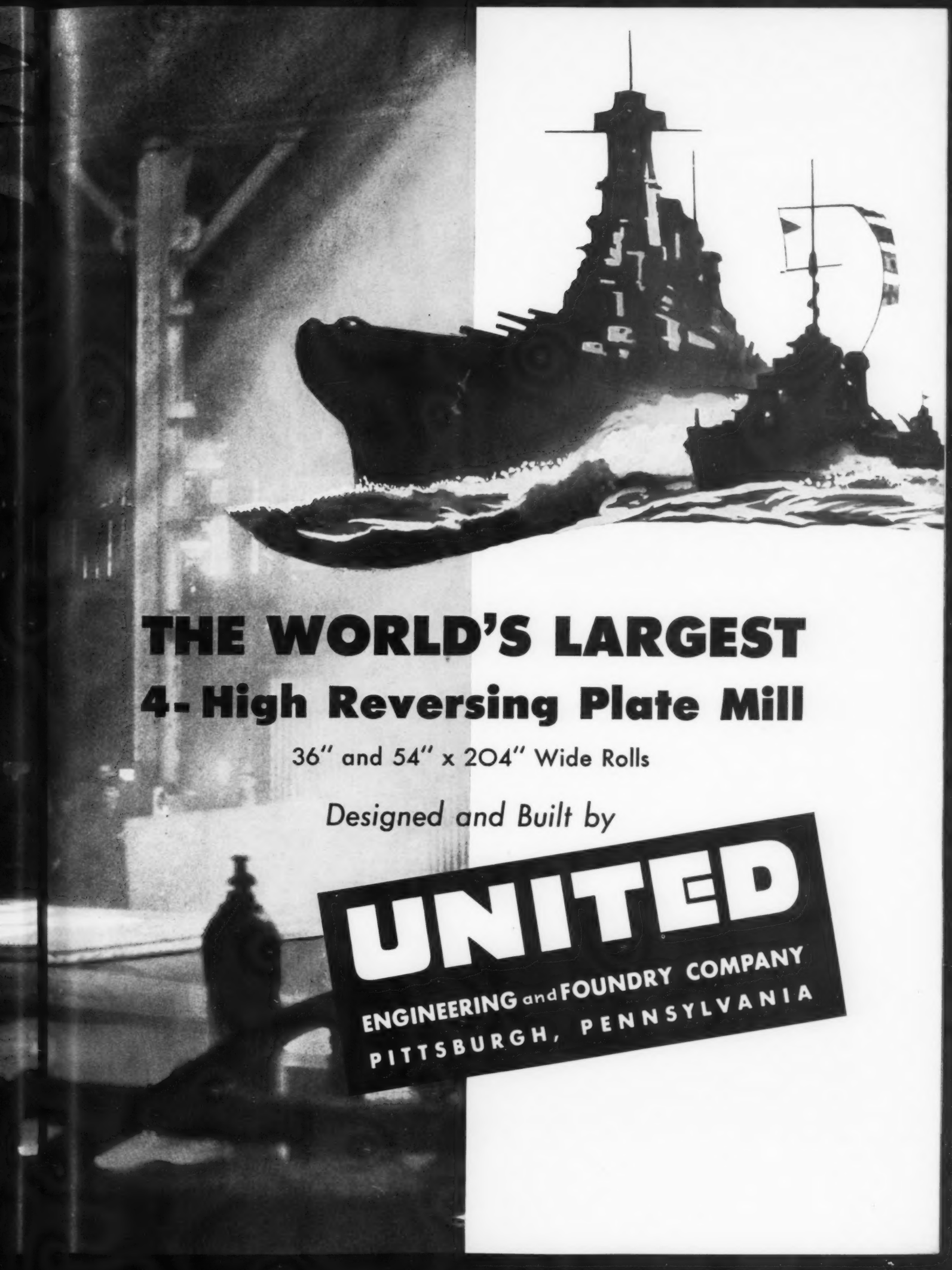


THE WORLD'S LARGEST
4-High Reversing Plate Mill

36" and 54" x 204" Wide Rolls

Designed and Built by

UNITED

ENGINEERING and FOUNDRY COMPANY

PITTSBURGH, PENNSYLVANIA

I feel like an Admiral!

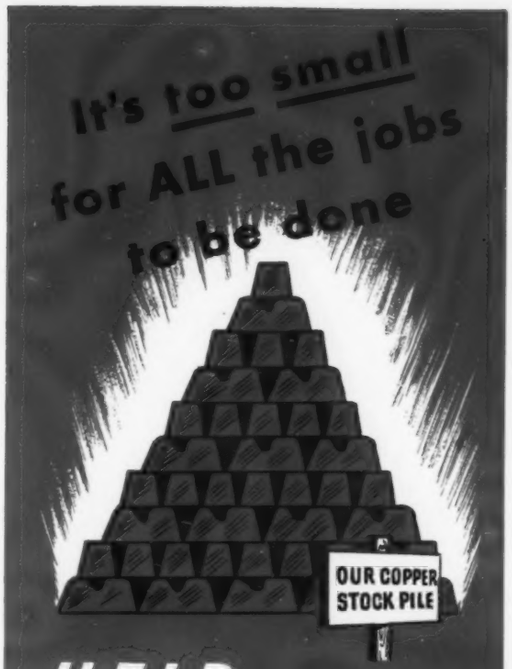
"Up here I'm rolling steel that won't stop rolling until it hits the Axis in the Axis!

"Me? I'm just a guy with a lot of levers, but I feel like an Admiral! Why? Because that Morgan Mill down there obeys me like a squadron!

"Sure I like my job . . . we get things done!"

R-107

MORGAN CONSTRUCTION COMPANY • WORCESTER, MASS.



HELP
S-T-R-E-T-C-H IT

Consider these things when figuring motor sizes

Don't overlook this hidden factor

Both N.E.M.A. and A.S.A. Standards specify that general-purpose electric motors shall be suitable for carrying CONTINUOUSLY a load of 1.15 times the rated load. Thus, a 5 hp. motor can carry 5¾ hp.

Make use of this. Save a frame size and S-T-R-E-T-C-H vital materials — copper, steel, aluminum.

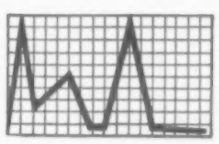
RELIANCE

WITH *copper* one of our most critical materials it's *our* job and *your* job to see that it gets to the spot where it does the most damage to our enemies. You want more motors. We shall have less copper for building them.

Here are some of the things that can be done about it:

Make more careful studies of machine loads. Don't over-motorize just to "play safe." We are in a spot where we must do some conservative gambling.

CHECK DUTY CYCLE . . . . Maybe an intermittent-duty motor will do, using a frame size smaller than the continuous-duty motor.



CHECK TORQUE REQUIREMENTS. Maybe a motor with special torque characteristics will take a frame size smaller and save vital materials.

CHECK SPEEDS. If it's a constant-speed motor, save a frame size by going to next higher speed, 1200 rpm. instead of 900 rpm.; 1800 rpm. in place of 1200 rpm.

If it's an adjustable-speed d-c. drive, can you get by with a higher minimum speed? A 1 to 3 range instead of 1 to 4? For example, using 500-1500 rpm. in place of 400-1600 rpm. saves a frame size.

Could you get along with a single-speed a-c. motor or a single-winding multi-speed motor instead of a two-winding multi-speed motor?

CHECK VOLTAGES. Specify single-voltage a-c. motors. They use but 3 leads instead of 9.

This job involves Application Engineering, which is our business. Reliance men skilled in this work are ready to help and are available in the industrial centers listed below.

RELIANCE ELECTRIC & ENGINEERING COMPANY
1088 IVANHOE ROAD • CLEVELAND, OHIO

BIRMINGHAM • BOSTON • BUFFALO • CHICAGO • CINCINNATI • DETROIT
GREENVILLE, S. C. • HOUSTON, TEXAS • LOS ANGELES • MINNEAPOLIS
NEW YORK • PHILADELPHIA • PITTSBURGH • PORTLAND, ORE. • ST. LOUIS
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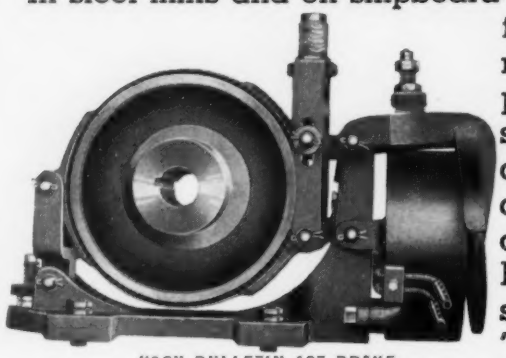
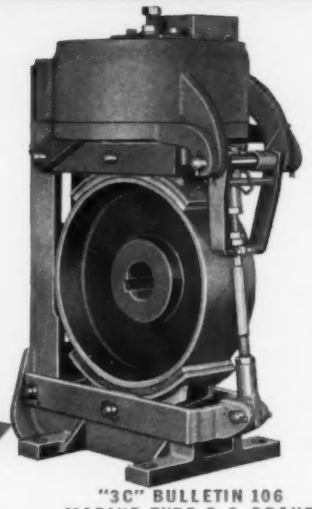
RELIANCE A-C D-C MOTORS

"3C" DEVELOPMENTS, ORIGINALLY FOR STEEL MILLS, ARE NOW ADAPTED TO SERVE ON THE SEVEN SEAS!

In steel mills and on shipboard Electric Control Apparatus has to be tough! Production in steel mills can't wait for lengthy repairs or maintenance—on the sea, lives depend upon immediate, accurate response in electric control. "3C" Brakes, long standard in Heavy Duty Operations, have been turned on end to save space, and adapted by "3C" Engineers to seagoing use.



"3C" BULLETIN 107 BRAKE

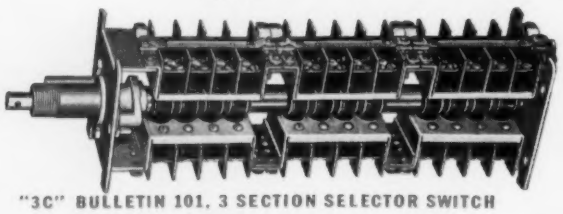


"3C" BULLETIN 106
MARINE TYPE D. C. BRAKE

Mill Master Switches—used to rough treatment, practically constant operation, and minimum maintenance, have been enclosed in a special water-tight, corrosion resisting housing, mounted on a pedestal, and are giving splendid service on shipboard. This service is possible because of the rugged construction, excellent engineering, and time tested materials used in making them.

"3C" BULLETIN 101
MILL MASTER
SWITCH

"3C" BULLETIN 101
PEDESTAL TYPE MASTER SWITCH

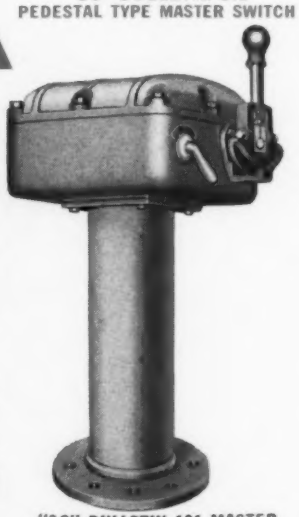


"3C" BULLETIN 101, 3 SECTION SELECTOR SWITCH

Here "3C" Engineers have combined a Selector Switch with a Mill Master Switch and put both in a water tight, pedestal mounted, corrosion resistant enclosure. This combination offers not only convenience but also safety of operation. The Selector Switch can, at will, cut in or cut out circuits used for operating other apparatus, thus preventing jamming at crucial points.

These are a few examples of the adaptation of "3C" devices to applications brought about by war conditions, and "3C" apparatus is delivering the same reliable service it has given for years in peacetime industry.

"3C" BULLETIN 101
MILL MASTER SWITCH



"3C" BULLETIN 101 MASTER
SWITCH WITH SELECTOR SWITCH

CONTINUE TO ROLL WITH CLARK CONTROL

THE CLARK CONTROLLER CO.

1146 EAST 152ND ST. CLEVELAND, OHIO

Schloemann Installations in a plate mill at Pittsburgh

Left—"Motor-Roller" equipped Scale Table

Below—
"Motor-Roller" equipped Shear Depressing Table

EXCLUSIVE ADVANTAGES

of

SCHLOEMANN "MOTOR-ROLLERS"

With the rotating trunnion-type roller housing the driving motor, the necessity for using line shafts, couplings and gear reduction units is eliminated. Simplified table construction is the result, affording free access along both sides of "Motor-Roller" Tables.

Installation of rollers between the housings of Mill Stands and Shear Housings is possible without introducing complicated or weak elements.

Fewer wearing parts provide the ruggedness and dependability essential in mill service with reduced operating and maintenance costs.

Each "Motor-Roller" installation is designed and built for the particular requirements of its application.

SCHLOEMANN

ENGINEERING CORP. PITTSBURGH, PA.

Rolling Mill Machinery Hydraulic Presses

Synthite* PG-1

HIGH SPEED INSULATING VARNISH

- High Dielectric Strength
- Glossy, Tough Film
- Good Adhesion
- Deep Drying
- Waterproof
- Oilproof

Especially developed to stand up under the extremely high speeds attained by motors in these types of applications, SYNTHITE PG-1 Clear Baking Varnish possesses the essential bonding properties which will hold windings intact under terrific centrifugal force. Ideally suited for use on the modern types of coated wires, such as Formvar, Formex, Nylon and Fiberglas, this DOLPH product will dry hard even in the deepest interstices of large coils.

SYNTHITE PG-1 is not an oxidizing type of varnish; thus danger of surface sealing is eliminated. Curing takes place through polymerization which solidifies the entire mass. There are no wet spots nor any trapped solvents. The armature shown above, graphically illustrates the thoroughness of this curing. A section was purposely cut away with a hammer and chisel. Even under this terrific impact, the wires and cord are intact.

Shipped at a gravity of 19° Baumé, SYNTHITE PG-1 Clear Baking Varnish provides a build-up of 3½ mils per coat, with a dielectric strength of over 1800 volts per mil. When required, DOLPH'S #170 is the appropriate thinner for this material. More detailed information regarding SYNTHITE PG-1 will be sent on request; write today.

*Reg. U. S. Pat. Off.

This actual test proved that SYNTHITE PG-1 cures evenly in any winding regardless of depth. A one pound can was filled with varnish and placed in a baking oven. As the solvent evaporated, fresh varnish was added so that a uniform depth of two inches was maintained. After continued baking, the can was cut in half with the results pictured. There were no wet spots, nor trapped solvents.

Dolph's

JOHN C. DOLPH COMPANY

Insulating Varnish Specialists

166A EMMETT ST. NEWARK, N. J.

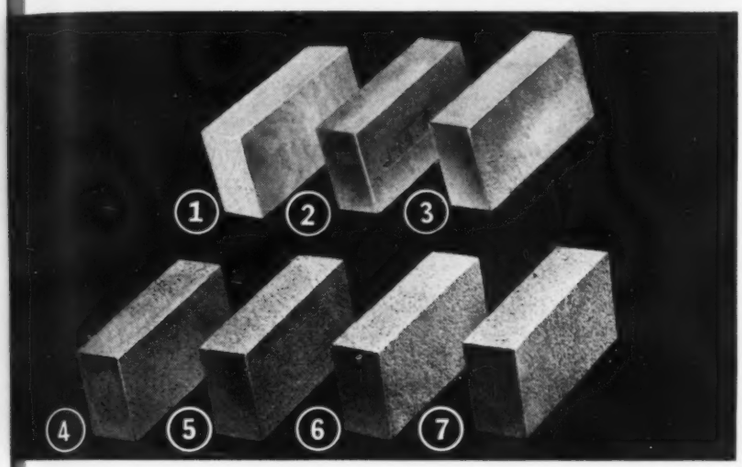
For the

BIG INSULATING JOBS

In the Iron and Steel Industry...

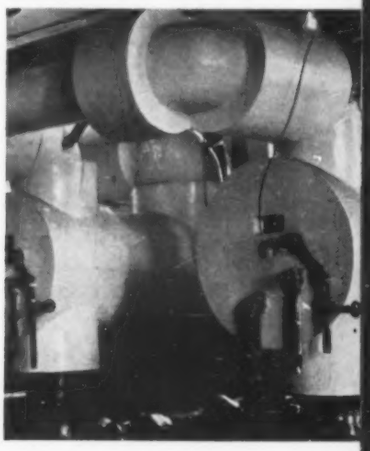
Lastingly Efficient Block Insulation...

J-M Superex meets every steel-mill requirement for temperatures to 1900° F. Combines high heat resistance and great durability with exceptional insulating value. Standard sizes 3″x18″, 6″x36″ and 12″x36″; from 1″ to 4″ thick. Other sizes and thicknesses on order. J-M 85% Magnesia or Asbesto-Sponge Felted are often used outside of Superex, which construction is known as J-M Superex Combination Insulation.



Seven Types of Brick...

Three types of insulating brick: (1) Sil-O-Cel Natural Brick for temperatures to 1600° F.; (2) Sil-O-Cel C-22 Brick for temperatures to 2000° F.; (3) Sil-O-Cel Super Insulating Brick for temperatures to 2500° F. Four types of insulating firebrick—(4) JM-16 for temperatures to 1600° F.; (5) JM-20 for temperatures to 2000° F.; (6) JM-23 for temperatures to 2300° F.; (7) JM-26 for temperatures to 2600° F. All provide light weight, low cost, low conductivity. Furnished accurately sized in all standard sizes of the 2½″ and 3″ series, as well as in specials.



Power Plant Insulations...

For many years the most widely used power plant insulations, Johns-Manville 85% Magnesia Blocks and Pipe Covering are today lighter in weight and more efficient than ever before. Standard-size blocks are 3″x18″, 6″x36″ and 12″x36″; from 1″ to 4″ thick. Other sizes, including lagging, furnished on special order. Pipe insulation is available in 3-foot lengths in thicknesses up to 3″. For temperatures above 600° F., Superex Combination Block or Pipe Insulation is recommended—an inner layer of high-temperature Superex and an outer layer of 85% Magnesia. Sizes same as those of 85% Magnesia.

Semi-Refractory Insulating Concrete...

Sil-O-Cel C-3 Concrete is the ideal material for lining furnace doors and for insulating furnace bases. Weighs less than half as much as firebrick; has 3 times greater insulating value. Cast on the job from Sil-O-Cel C-3 aggregate and cement. Sets up into a strong, durable concrete for temperatures up to 1800° F. Furnished in 100-lb. bags.

THESE ARE BUT A FEW of the many Johns-Manville Insulations that are helping assure dependable, uninterrupted operation of all types of heated equipment in the iron and steel industry. For details on all J-M Insulations, write for Catalog GI-6A. Johns-Manville, 22 East 40th Street, New York, N. Y.

JM Johns-Manville

INDUSTRIAL INSULATIONS

Save Critical Materials

Use this table as a guide for overloading Pennsylvania Power Transformers

Approximate Load in per cent of 55° C. Self-cooled Rating	Permissible Top-Oil Temperature
100%	75°C
115%	70°C
129%	65°C
142%	60°C
154%	55°C
166%	50°C

HOW TO USE OVERLOAD-TEMPERATURE TABLE

With any continuous load shown in the first column of the table, the top oil temperature in the transformer should not exceed the corresponding value shown in the second column. Intermediate values may be obtained by direct interpolation.

EXAMPLE: If a transformer, while carrying 100% load, is found to have a top oil temperature of 75° C., and it is desired to carry 29% overload on this transformer, additional cooling must be provided to bring the top oil temperature down to 65° C., when the transformer is carrying 129% load.

• • •

It is not always necessary to provide additional cooling in order to obtain additional capacity. Low ambient temperature, low load factor, and similar conditions will permit the transformer to be overloaded to the extent shown in the table, as long as the corresponding permissible oil temperatures are not exceeded.

ADDITION OF FORCED COOLING

Increased rating may be obtained economically by the addition of forced-air-cooling fans, or forced-oil-cooling units. For information as to type, number, and size of fans and cooling units, you are invited to consult our Engineering Department.

LIMITATIONS

The above guide applies to Pennsylvania Power Transformers which have been properly operated and maintained. The oil must be in good condition as indicated by dielectric strength and color. Samples of oil may be sent to our factory where they will be tested without charge.

Before applying overloads to transformers, a careful check should be made of the thermal capability of all associated equipment, such as circuit breakers, switches, current transformers, cables, meters and relays. Before exceeding 135% load on any transformer, it is recommended that advice be obtained from our Engineering Department as to any limitations involved, such as oil expansion, pressure in sealed-type units, bushing ratings, etc.

Pennsylvania TRANSFORMER COMPANY

808 RIDGE AVENUE, • N. S., PITTSBURGH, PA.

A. I. S. E. STANDARD CRANE SPECIFICATIONS

1. Explanation:

These specifications cover heavy duty, mill type, overhead traveling cranes. All cranes for ...

Crane Specification. It shall be referred to in all contracts as such and shall form part of such contracts ...ached to same or not. ...e known as contractor's ...ns shall take precedence ...s and shall be strictly ...fications or understand- ...greed to in writing. ...ser stating sizes, special ...all be known as "pur- ...Where the requirements ...r from specification, the

...er showing specific data ...oses to furnish, shall be ... contractor's information sheets."

Where contract covers a number of cranes, this specification shall apply to each and every one.

In addition to specifications furnished with proposition, contractor shall furnish the required number of copies of his specification for the purchaser's file.

...ether on the ...ley motor shaft ...dy on the periphery of one of the trolley track wheels.

38. Brakes:

BRIDGE BRAKES:

1. Each bridge drive shall be equipped with hydraulic brake or brakes, of sufficient size to stop crane within a distance in feet equal to ten per cent of full load speed in feet per minute, when traveling at full speed with full load. The size of brake furnished shall be the responsibility of the contractor.

2. The stroke of the bridge brake foot pedal shall not be more than 8 in. and lever shall be so designed that it will not interfere with necessary movements of operator's legs or feet while operating the crane.

3. In addition to the hydraulic brakes, all cranes with anti-friction bearings on the bridge drive designed for more than 300 fpm brid... with dynamic braki... ...ovided

4. If specifi... provided wit... drive, so a... disconne... opened...

5... the ...

m...

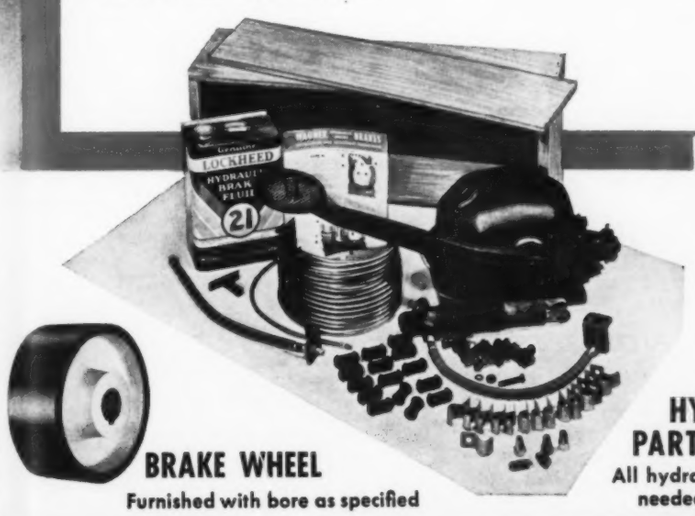
WAGNER HYDRAULIC BRIDGE BRAKING SYSTEMS MEET ALL A. I. S. E. SPECIFICATIONS!

★ ★ ★ ★ ★ ★ ★

In addition to meeting all of the requirements of the Association of Iron and Steel Engineers, Wagner Hydraulic Bridge Braking Systems have features that make them the choice of most of the large crane manufacturers. A few of the many points of excellence are:

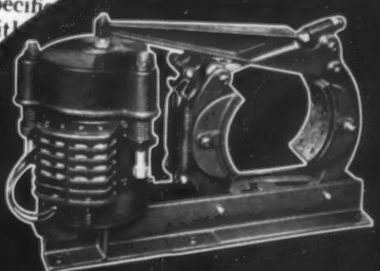
1. Easy one-point adjustment . . . 2. Exclusive anti-drag device . . . 3. They have hardened pins, knurled to prevent rotation . . . 4. They have bushings at points of maximum wear . . . 5. Grease fittings are provided on all hinge pins . . . 6. The friction blocks are extra thick, and bolted to the shoes . . . 7. Wagner provides nation-wide service through twenty-five branches . . . 8. Wagner Hydraulic Braking Systems come to you in complete kits ready to install. They include brake assembly, brake wheel, master cylinder, wheel cylinder, copper tubing, flexible hose, brake fluid and all fittings.

If you are planning on new cranes or conversion from mechanical brakes, it will pay you to investigate the many advantages of Wagner Hydraulic Bridge Braking Systems. Trained field engineers in all of the Wagner twenty-five branches located in principal cities will be glad to consult with you. Bulletin IU-20 will be sent upon request.



BRAKE WHEEL
Furnished with bore as specified

HYDRAULIC PARTS and FLUID
All hydraulic parts and fluid needed for installation.



TYPE HM — Wagner hydraulically actuated bridge brake with automatic parking attachment for outside cranes.

TYPE H — Wagner hydraulically actuated bridge brake for inside cranes.

I42-13

BUY U.S. WAR BONDS

Wagner Electric Corporation
6400 Plymouth Avenue, Saint Louis, Mo., U.S.A.
BRIDGE BRAKES • MOTORS • TRANSFORMERS

Cut Shut-Down Time

with Heppenstall Shear Knives

You'll change knives less often if you use Heppenstall Shear Knives. They cut cleaner and stay in the shears longer between grinds, because they are made of the finest special analysis alloy steel in Heppenstall's own electric induction furnaces. Forging, annealing, machining, heat treating, and grinding are all done with meticulous care according to methods developed through more than fifty years of quality shear knife manufacture. • Let Heppenstall Service Engineers add their experience to yours and help you solve shearing problems. Call upon them without obligation. And next time you order, specify Heppenstall. Use knives that deliver more tons per grinding. Write for full information, Box E2, Heppenstall Co., 4620 Hatfield St., Pgh., Pa.

Heppenstall

PITTSBURGH DETROIT BRIDGEPORT

HEPPENSTALL H QUALITY

Forging Fine Steels for More Than Fifty Years

STOP LOSSES ... FROM CORROSION AND THERMAL SHOCK

IN EQUIPMENT DESIGNED FOR THE PRODUCTION OR USE OF

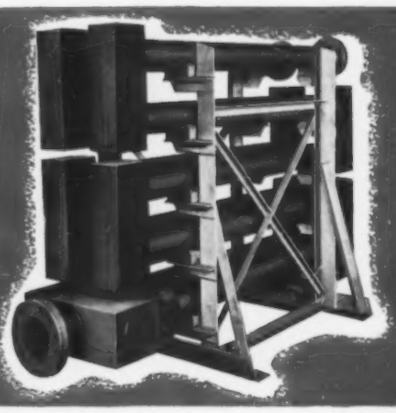
Hydrochloric Acid

BY USING

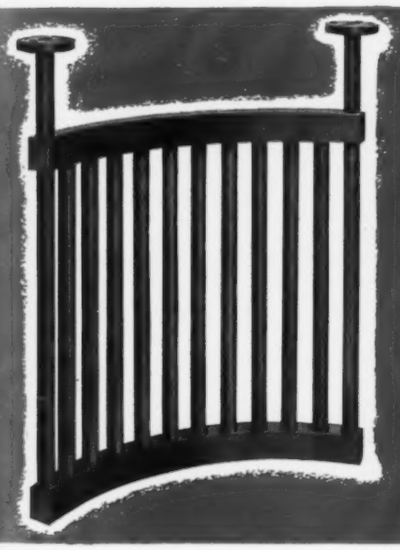
National
TRADE-MARK

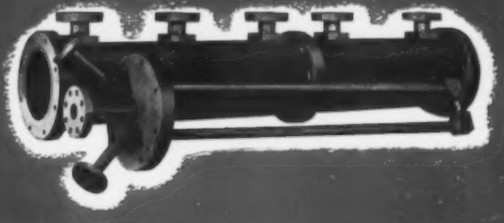
AND Karbate*
TRADE-MARK

CARBON AND GRAPHITE MATERIALS



FOR THE CONSTRUCTION OF PROCESSING UNITS





* The words "National" and "Karbate" are trade-marks of National Carbon Company, Inc. The trade-mark "Karbate" identifies a line of carbon and graphite base materials impervious to seepage of liquids and gases under pressure.

● Carbon, graphite and "Karbate" materials are used in the construction of equipment for all processes involved in the manufacture or use of hydrochloric acid. This includes absorbing, cooling, rectifying, boiling and condensing units, conveying and circulating systems, vats, tanks and other containers.

These materials are resistant to the action of hydrochloric acid in all phases and concentrations. The excellent heat transfer properties of graphite base materials are of advantage in equipment used for heating, cooling and stripping processes. Good mechanical strength, exceptional resistance to thermal shock, ease of machining, and availability in a wide variety of forms adapt these products to the fabrication of practically any desired type of processing equipment.

EXPERIENCE HAS PROVED THE DURABILITY OF CARBON AND GRAPHITE MATERIALS IN THE PRESENCE OF HYDROCHLORIC ACID AND THE ECONOMY RESULTING FROM THEIR USE

WHATEVER YOUR PROBLEM — *Consider Carbon and Graphite* — WRITE FOR INFORMATION

NATIONAL CARBON COMPANY, INC.
Unit of Union Carbide and Carbon Corporation

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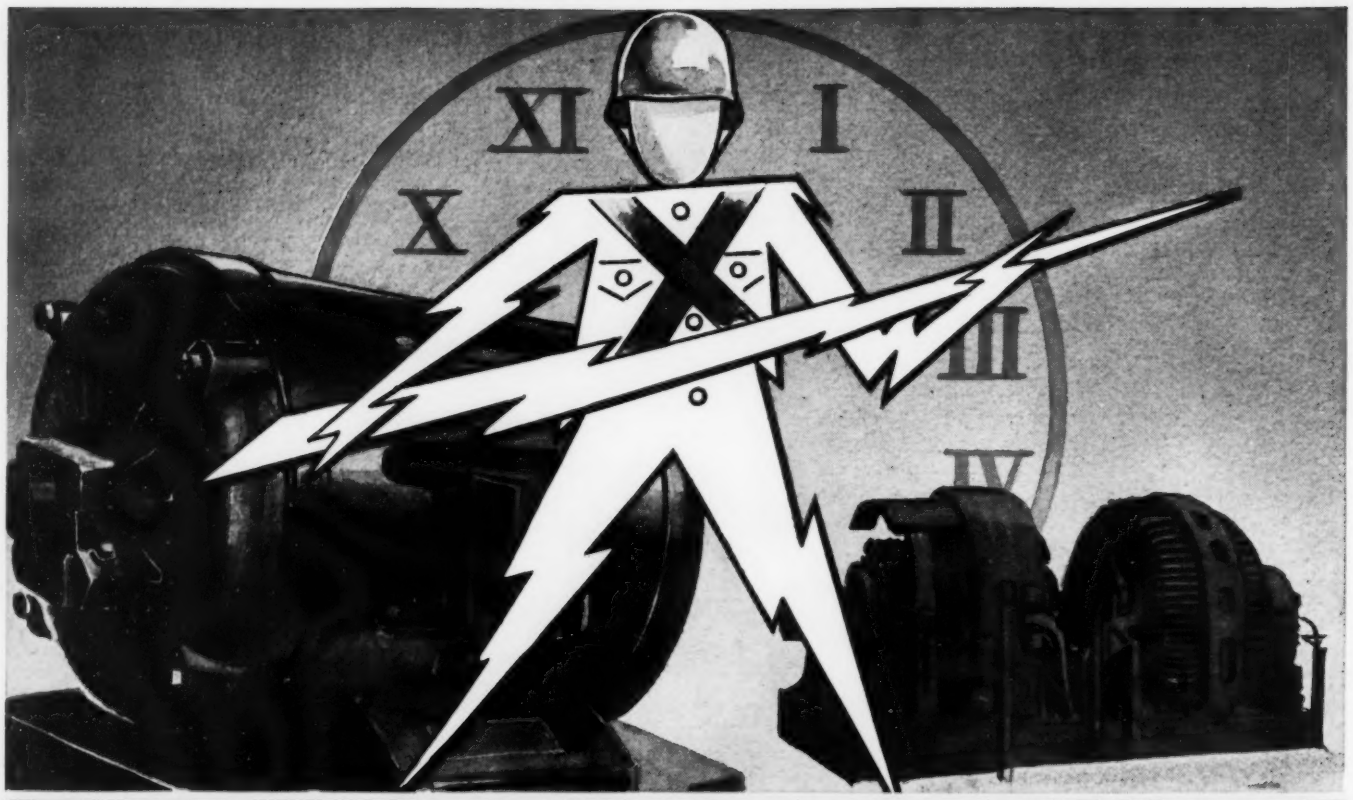
Carbon Sales Division, Cleveland, Ohio
GENERAL OFFICES
30 East 42nd Street, New York, N. Y.
BRANCH SALES OFFICES
New York, Pittsburgh, Chicago, St. Louis, San Francisco



A CALL TO THE COLORS FOR EVERY AVAILABLE WATT-HOUR

No time now for a single watt-hour of energy to be wasted, for this is a war of power. Every available source of energy must work war-time hours. No motor or generator can be allowed to shirk its duty.

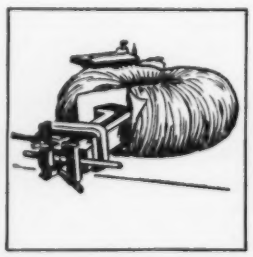
War-condition your electrical equipment! And don't forget that an apparently little thing like a slight difference in brush grades can pep up an electrical machine like a shot of adrenalin in a scared rabbit.

So here is a war service offered by SPEER, backed by nearly a half century of research and experience in the production and use of carbon products. On request, SPEER will send you, without obligating you in any way, recommendations covering the type and grade of brushes best for your machines. All you need do is to write for a set of SPEER Brush Data Forms — one for each machine whose performance you wish to improve — and mail them to us. Our commutation engineers will study your data and send you their recommendations. The rest is up to you.

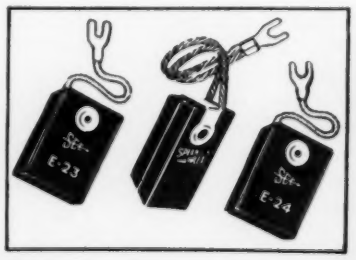
PROMOTE COPPER SALVAGE

Save the shunts and connections from discarded brushes. This helps to salvage copper needed for war material. Keep it moving to your salvage dealer as fast as it is accumulated.

Famous American Firsts



Thomson's Welding Transformer, 1885.



SPEER BRUSHES— To meet the requirements of most industrial motors, SPEER Electro-Graphitic Brush grades E-23 and E-24. Also available as Multiflex Brushes. Write today for complete descriptive catalog.
There is *one right* brush grade for every job—and SPEER makes it.

SPEER
CARBON COMPANY
ST. MARYS, PA.
CHICAGO · CLEVELAND · DETROIT
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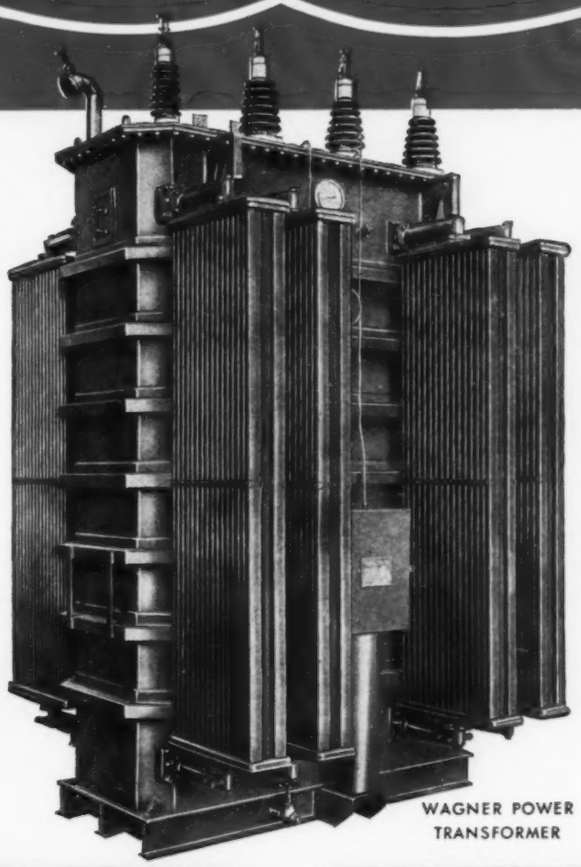
8780

The "EXTRA MARGIN OF SAFETY" built into WAGNER TRANSFORMERS gives ADDED PROTECTION!



WAGNER POWER TRANSFORMER

The steel industry, in its effort to keep production rolling at top speed, is imposing extra loads on all production equipment. Transformers are no exception—they too must be able "to take it", and "come up smiling."

Liberal insulation—extra end turns on coils provide liberal protection against line surges and voltage disturbances . . . Heavy tank construction—heavy steel plate, electrically welded, sand-blasted and flow-painted . . . Core iron of non-aging silicon steel—has high magnetic permeability and has very low hysteresis and eddy-current losses . . . Stationary contacts—of hard-drawn copper, sweated and pinned into brass-shouldered studs . . . Bushings—wet-processed porcelain, either solid or oil-filled with sufficient mechanical and electrical strength to carry the load without puncturing . . . Transformer oil—has high dielectric strength, proper viscosity, safe flash-point, and will not sludge.

These are just a few of the superior characteristics of Wagner Transformers which give that "Added Margin of Safety". In addition, carefully controlled production methods, rigid inspection, plus 50 years of transformer engineering experience, assure users of Wagner Transformers the highest efficiency and stamina so necessary for the demands of today's stepped-up production.

No matter what your transformer requirements may be, the Wagner line will meet your requirements. Wagner Transformers range from small air-cooled to large oil-filled power transformers—and the same high quality goes into the construction of each one.

WAGNER NOFLAMOL TRANSFORMER

WAGNER AIR-COOLED TRANSFORMER

WAGNER HEX TRANSFORMER

SEND FOR COMPLETE LITERATURE TODAY!

WAGNER ELECTRIC CORP., ST. LOUIS, MO., U. S. A.

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I&SE

Gentlemen:
Please send me bulletins TU-180 and TU-181.

Name_____ Position_____

Firm_____

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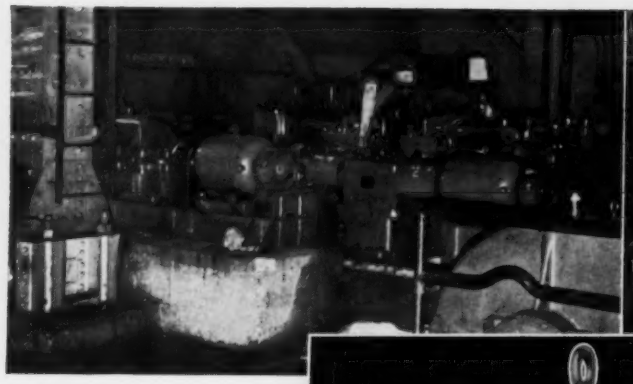
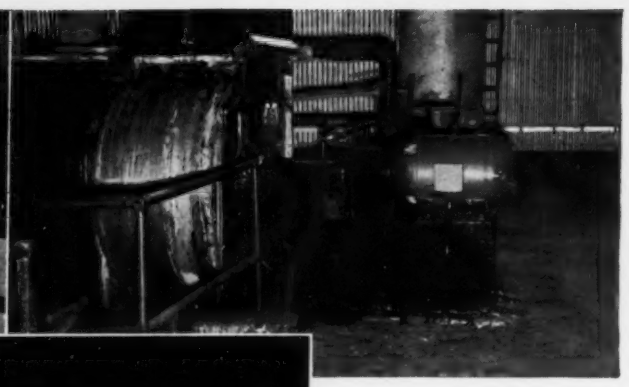
Wagner Electric Corporation

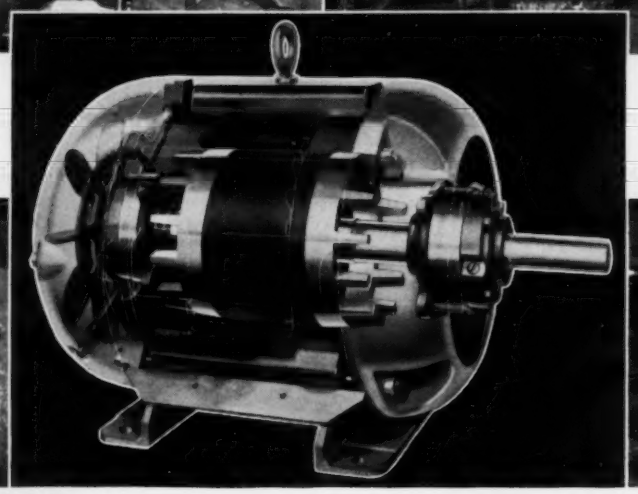
6400 Plymouth Avenue, Saint Louis, Mo., U.S.A.

TRANSFORMERS • MOTORS • FANS • BRAKES

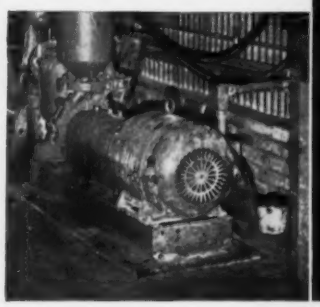




Typical installations showing Wagner CP motors on the job, giving dependable service in steel plants. Thousands of these motors, now driving equipment in the steel industry, have proved their reliability.



The phantom illustration, at left, shows the sturdy construction of Wagner CP motors. No acid fumes, steam, or conductive or abrasive dust, can reach the vital parts to cause damage to the motor.



Here's WHY WAGNER *CP* MOTORS CAN DO AN *"ALL-OUT"* JOB FOR YOU....

In steel plants, where dust, dirt, abrasives, steel chips, filings, acid fumes, and other harmful elements are present, Wagner CP motors can perform an "all-out" service.

Here are a few of the many reasons why Wagner CP motors stay on the job and give longer service.

1..Two-frame construction—an outer frame guides a strong, cooling draft over the motor, while an inner frame completely seals the vital parts of the motor against the entrance of destructive or injurious materials. **2**.. Rugged, welded all-steel stator with specially impregnated windings. **3**.. Dynamically balanced rotor, equipped with sturdy shaft having all keyways end-milled. **4**.. Full-cartridge-bearing construction which completely seals and protects the ball bearings. **5**.. Easily accessible grease plugs, permitting lubrication without removing fan shield or stopping motor. **6**.. End-plates heavily and ruggedly constructed, with air deflector on shaft end. **7**.. Single-end ventilation with non-clogging, one-piece fan of split-hub construction. **8**.. Fan shield which is formed from sheet steel, can be easily removed for access to fan. **9**.. Nine leads connectable for either 220 or 440 volts completely sealed in outlet, making it impossible for abrasive materials to enter motor.

Field Engineering Service!

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LOAD THRUST BEARINGS at RIGHT ANGLES to the axis of rollers...

For highest efficiency, most Radial bearings are loaded at *right angles* to the roller axis. Bearings loaded that way last longer, have greater resistance to shock and vibration.

But how about THRUST—the FORGOTTEN BEARINGS of Industry? Too frequently thrust loads are dumped onto the same bearing that carries the radial load—usually at acute angles that veer 15° to 40° from the perpendicular. No wonder the rollers tend to slide out from under the load. No wonder they wear against the radius of the race, building up high torque loads, setting up complicated internal stresses.

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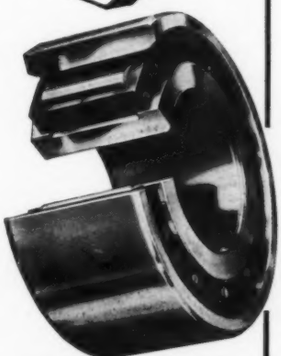
The available types and series of Rollway Solid Cylindrical Roller Bearings run into the hundreds—each engineered to standard metric dimensions and tolerances, and to specific uses. No extra tooling, no special machine setups are necessary to fill an order. You get faster service, easier replacements and lower cost.



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BUILDING HEAVY-DUTY BEARINGS SINCE 1908 — BEARINGS

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(quoted from a letter, dated Sept. 5, 1942, conferring the Army-Navy "E" on Union Steel Castings Division of Blaw-Knox Co.)

To us, this "E" is far more than a source of pride. It is our inspiration to do even better in the future than we have in the past. It shall serve as a constant reminder of our pledge to give all our strength, all our time, all we have and are to the cause of Liberty.

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DIVISION OF
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The Isley System of Push-Pull Ejectors provide a *mechanical draft* which *pushes in* air for combustion . . . *pulls out* products of combustion. The push-pull action is strong . . . permits use of *extra regenerative chambers* . . . increases regenerative capacity by 50%! Absence of variable factors assures uniform operation at all times —regardless of weather conditions.

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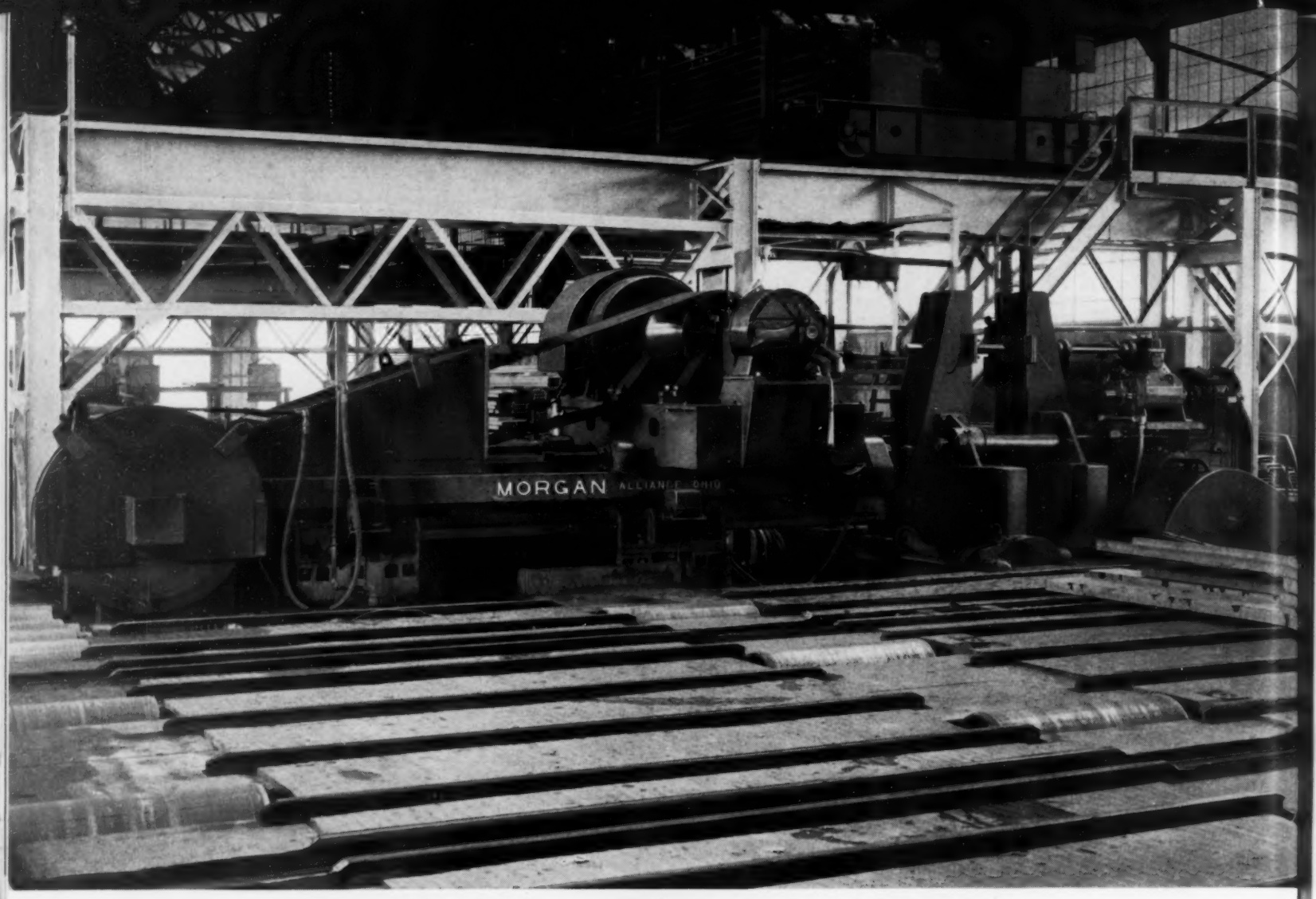

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At the rear of the saw is shown a Morgan Gag Straightener for straightening up to 24″ I beams.

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The LINK-BELT
Rotary R. R. Car Dumper Unloads up to 30 Cars per Hour

The many Link-Belt rotary railroad car dumpers now in service, are playing an important role in the battle of transportation. This unit is capable of unloading all types of open-top railroad cars—varying from 26 ft. to 60 ft. long; 7 ft. to 12½ ft. high; 8½ ft. to 11 ft. wide; and with capacities up to 120 tons. The number of cars it can handle in a given time depends upon the switching and track facilities for supplying loaded cars and removing empties. A full cycle of dumping and returning to normal position is accomplished in 1½ minutes. The whole operation is so simple, automatic and foolproof that unskilled labor can perform it readily; it is completely under control at all times and can be stopped instantly at any point of the cycle. Send for Book No. 1004.

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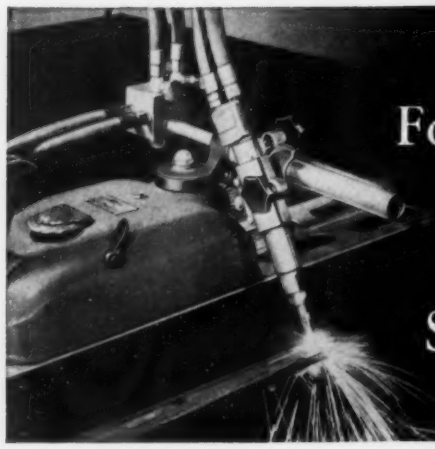

For better results in Oxy-Acetylene Machine-Cutting Operations . . . Send for this Descriptive Chart

SEVEN WAYS TO INCREASE MACHINE-CUTTING ACCURACY
1. Correct Cutting Technique. The surface is plane and regular, and the drag lines are practically vertical. The slight amount of adhering scale at the top of the cut due to the action of the preheat flames can be easily chipped off. This is an excellent surface and for many purposes can be used without machining.
2. Cutting Speed Too Low. Heat there is an excessive undercutting and adhesion of molten slag resulting in an extremely irregular surface. Also, with too low a cutting speed, there is an undue waste of oxygen and acetylene.
3. Cutting Speed Too High. Excessive cutting speed is shown by the angle of rake of the drag lines. Nevertheless, the surface is reasonably smooth and for normal production work would be satisfactory. However, there is danger of losing the cut, if the speed is increased above that indicated by this photograph.
4. Nozzle Too Far From Work. This results in excessive melting of the top edge. When cutting at normal speed and with correct nozzle clearance, the preheat flames should be in contact with the plate surface. At greater clearances, the heat is drawn in by the aspirating effect of the oxygen stream.
5. Nozzle Too Near The Work. In order to prevent popping of the flame, an excessive preheat flame has been used. A portion of the preheat cone burns inside the kerf, resulting in an unstable cutting action. This produces grooves and exaggerated drag lines.
6. Excess Cutting Oxygen. The combustion of steel follows the pattern of the oxygen stream. For a given nozzle size, excess oxygen consumption is caused by excessive oxygen pressure which, in turn, causes excessive expansion immediately below the orifice. This results in a distorted and unsightly cut.
7. Excess Preheat Flame. Inexperienced operators frequently endeavor to speed up the cut by using an excessive preheat flame. This does not affect speed of cutting, but merely serves to fuse the top edge of the metal. In addition, there is an unnecessary waste of gases.
8. Dirty Nozzle Used. The nozzle here has been fouled by some adhering scale with the result that the oxygen stream has lost its parallel form and the surface of the cut is no longer clear and regular. There is evidence of pitting, undercutting, and excessive scale. This can be remedied by cleaning the nozzle.
THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide and Carbon Corporation
New York and UCC Principal Cities
In Canada: Dominion Oxygen Company, Limited, Toronto
Printed in U.S.A. Form 4346 P 13050

Good results in oxy-acetylene machine-cutting depend not only upon the use of efficient equipment, but also upon flame adjustment, oxygen and acetylene pressures, cutting speeds, and correct operation of the machine. The chart illustrated is a convenient reference containing helpful information on how to increase machine-cutting accuracy. One photograph shows the excellent surface obtained as a result of correct cutting techniques. The other photographs clearly show the results of some of the most common faults of machine-cutting procedures. Operators can use this chart as a means of comparing the actual results of their cutting operations, and thereby help to maintain a high level of workmanship. Large reprints (9 by 11¼ inches) of these charts are available from any Linde office without charge. Ask for Form 4346.

Instruction Literature

For information on correct gas pressures, nozzle sizes, and cutting speeds, refer to the Instructions furnished with your Oxweld cutting machines. Duplicate copies of these Instructions are available from any Linde office.

THE LINDE AIR PRODUCTS COMPANY

Unit of Union Carbide and Carbon Corporation

General Office: New York, N. Y. UCC Offices in Principal Cities

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LINDE OXYGEN . . . PREST-O-LITE ACETYLENE . . . UNION CARBIDE
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The wide range of speed reduction available with De Laval worm gears facilitates standardization of motor speeds and favors the selection of high-speed motors, which cost less, save power and improve power factor, as compared with slow-speed motors. Ask for Publication W-1136.

DE LAVAL **WORM GEAR DIVISION**

of the De Laval Steam Turbine Co., Trenton, N. J.

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TO EXECUTIVES:

NOW YOU CAN HELP

Even More...

New Treasury Ruling Permits Purchases UP TO $100,000, in any Calendar Year, of Series F and G WAR BONDS!

The Treasury's decision to increase the limitations on the F and G Bonds resulted from numerous requests by purchasers who asked the opportunity to put more money into the war program.

This is not a new Bond issue and not a new series of War Bonds. Thousands of individuals, corporations, labor unions, and other organizations have this year already purchased $50,000 of Series F and G Bonds, the old limit. Under the new regulations, however, these Bond holders will be permitted to make additional purchases of $50,000 in the remaining months of the year. The new limitation on holdings of $100,000 in any one calendar year in either Series F or G, or in both series combined, is on the cost price, not on the maturity value.

Series F and G Bonds are intended primarily for larger investors and may be registered in the names of fiduciaries, corporations, labor unions and other groups, as well as in the names of individuals.

The Series F Bond is a 12-year appreciation Bond, issued on a discount basis at 74 percent of maturity value. If held to maturity, 12 years from the date of issue, the Bond draws interest equivalent to 2.53 percent a year; computed on the purchase price, compounded semiannually.

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Don't delay—your "fighting dollars" are needed *now.* Your bank or post office has full details.

Save With . . .

War Savings Bonds

This space is a contribution to America's All-Out War Program by Iron and Steel Engineer

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Deltabeston Cables are distributed nationally by Graybar Electric Co., G.E. Supply Corp. and other G-E Merchandise Distributors. For further information on this asbestos-protected cable, get in touch with your nearest Distributor or write to Section Y1023-31, Appliance and Merchandise Department, General Electric Co., Bridgeport, Connecticut.

GENERAL ELECTRIC

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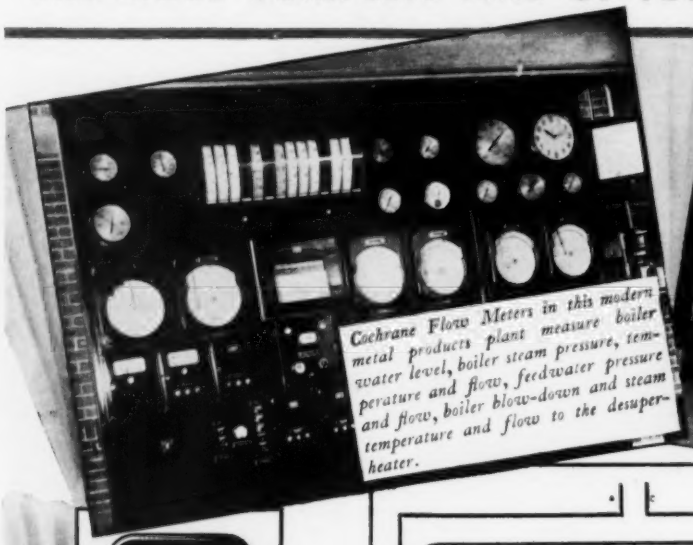
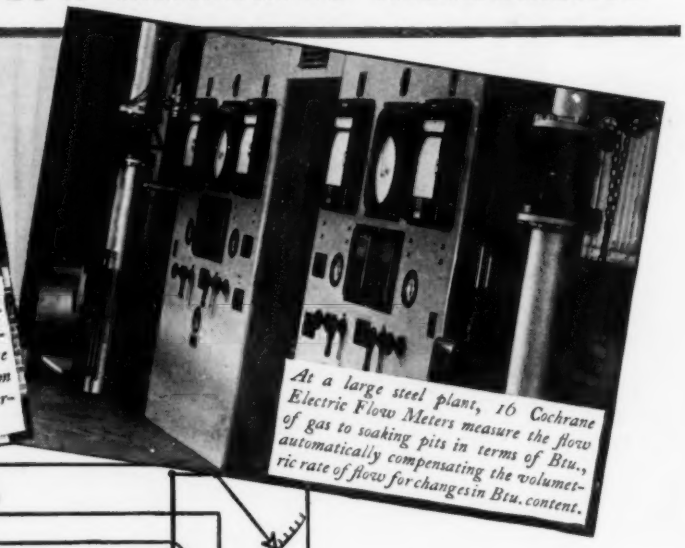
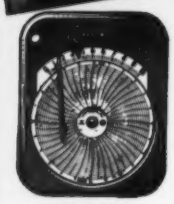
THE MOST COMPLETE LINE OF FLOW MEASURING INSTRUMENTS



Cochrane Flow Meters in this modern metal products plant measure boiler water level, boiler steam pressure, temperature and flow, feedwater pressure and flow, boiler blow-down and steam temperature and flow to the desuperheater.



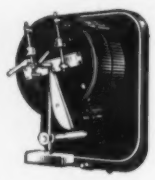
At a large steel plant, 16 Cochrane Electric Flow Meters measure the flow of gas to soaking pits in terms of Btu., automatically compensating the volumetric rate of flow for changes in Btu. content.



COCHRANE ELECTRIC METER

COCHRANE MECHANICAL METER

COCHRANE LINAMETER



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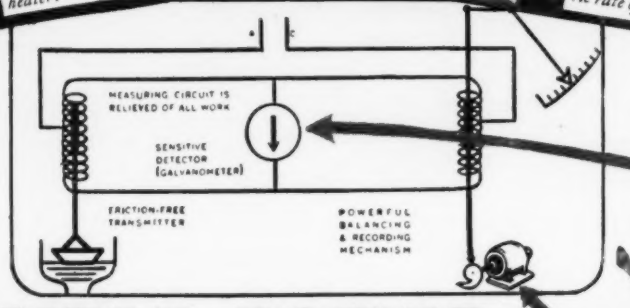
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POWERFUL BALANCING & RECORDING MECHANISM

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PILOT

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employed in the

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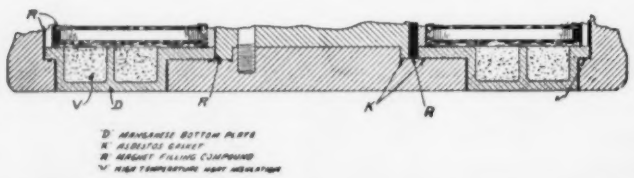

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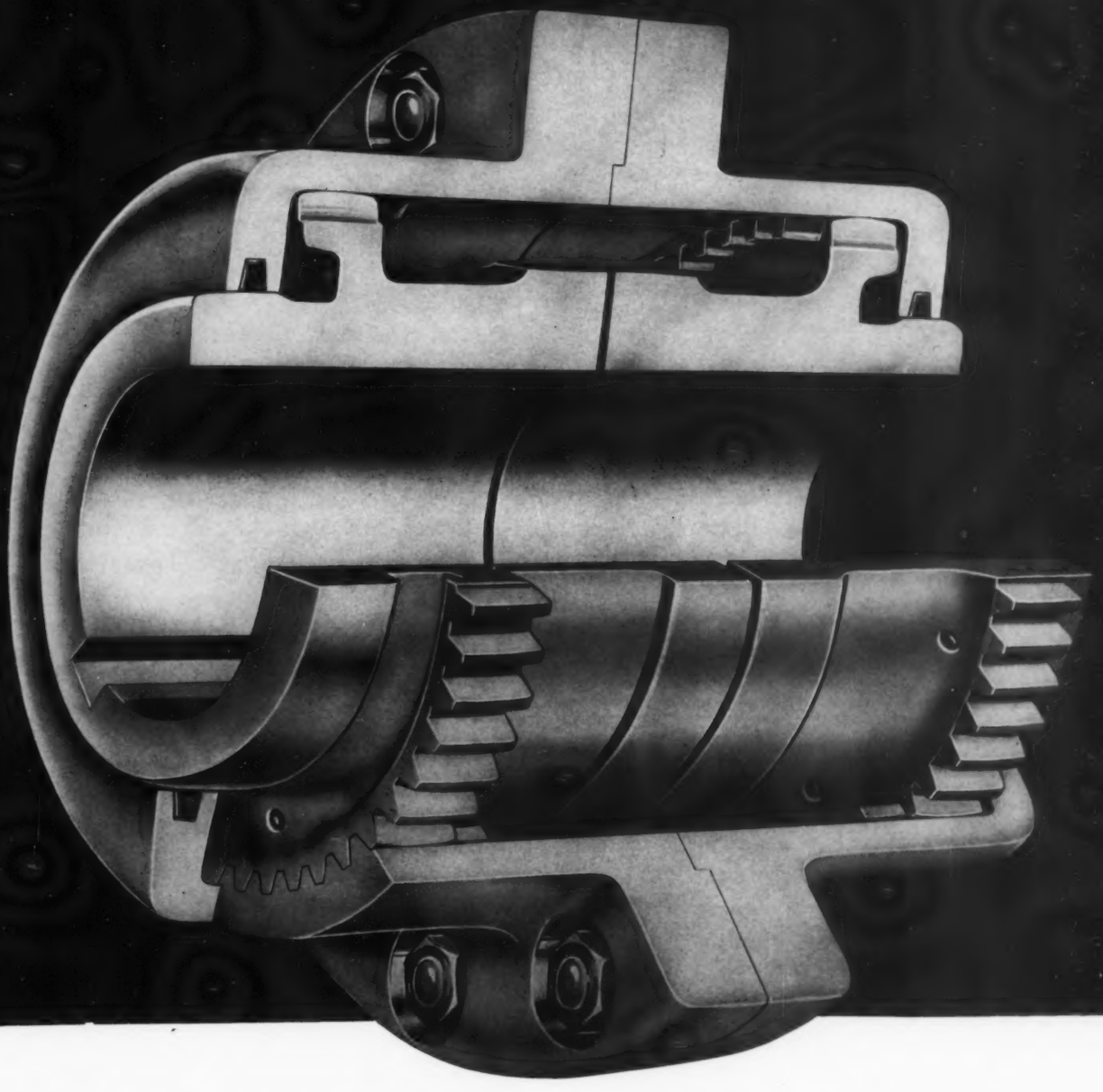

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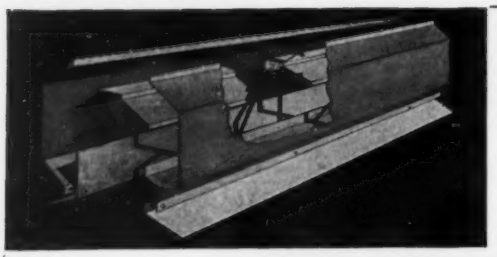
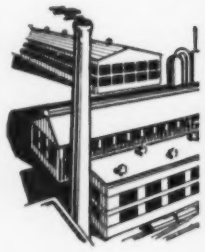
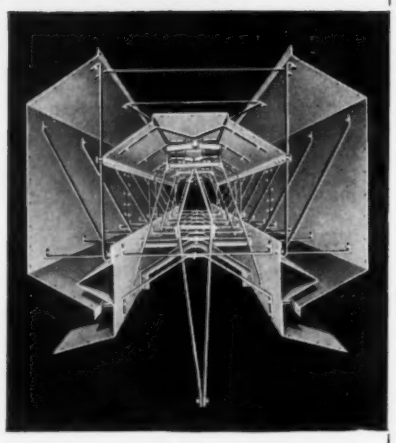


Cutaway View





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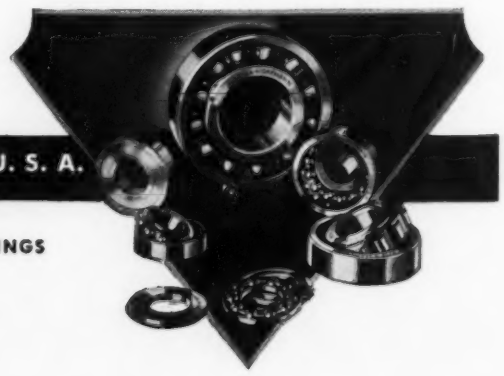
YOUR MACHINE EQUIPMENT

A treacherous, insidious saboteur lurks in every plant engaged in war production, alert to every opportunity to damage your machines and curtail your output. FRICTION is his name, and your only safeguard against him is the vigilant protection of F.B.I.—FREQUENT BEARING INSPECTION.

Keep all bearings clean and well lubricated. Exclude dust, dirt and moisture. Use only high-grade lubricants. Watch for the first signs of unusual heat or noise or looseness in the bearings. If possible, keep replacement bearings at hand, for a quick substitution if needed. America, in her vast war program, cannot afford to lose a single machine-hour of production. Guard against such losses by FREQUENT BEARING INSPECTION.

We will gladly cooperate with you in maintaining or increasing your production—by experienced counsel on the use and care of anti-friction bearings, and by supplying you, wherever possible, NORMA-HOFFMANN PRECISION BEARINGS for replacements.

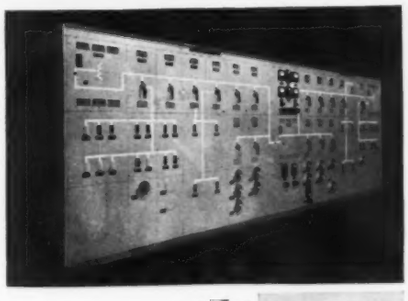
Write for the Catalog. Let our engineers work with you.



NORMA-HOFFMANN BEARINGS CORP'N., STAMFORD, CONN., U. S. A.
FOUNDED 1911

PRECISION BALL, ROLLER AND THRUST BEARINGS

ON BUS DUCTS OF THE PLUG-IN TYPE CIRCUIT BREAKERS are by I-T-E



These are readily identified as the work of I-T-E

Steel-enclosed switchboards and individually mounted circuit breakers have carried the I-T-E symbol into the plants of industry. These units represent the work for which I-T-E is known. But, as the text at the right indicates, the field of I-T-E usefulness is even greater.

BRINGING CURRENT to a production machine, wherever needed in a plant, is as easy with plug-in bus ducts as connecting an electrical appliance at home. Openings in a duct are spaced but a few inches apart, permitting connection to the bus at the point of greatest convenience. There is no interruption of service on the bus.

I-T-E contribution to this modern development – – the most economical, convenient, flexible and salvageable of layouts – – is the circuit breaker which is enclosed in many plug-in devices. With the box-cover closed, it is likely that attachments are frequently made without knowledge of the I-T-E equipment and the important part it plays.

This use of circuit breakers in plug-in bus ducts is another example indicating that the field of usefulness for I-T-E products is wide.

Representatives in Principal Cities

I-T-E

AIR SWITCHGEAR
IMMERSED IN AIR — ENCASED IN STEEL

The Army-Navy "E" for Production Excellence

I-T-E

CIRCUIT BREAKER CO., PHILADELPHIA, PA.

TOUGH from the INSIDE OUT

ARMATURE OF THE NEW G-E D-C MOTORS

TOUGH INSIDE
Windings of Formex magnet wire, with toughest insulation yet developed

TOUGH OUTSIDE
Windings bonded and protected by durable Glyptal synthetic resins

OTHER "TOUGHNESS" FEATURES
Shaft of high grade steel, accurately machined, and with ample fillets to withstand severe mechanical shock • Core of annealed, nonaging silicon steel • Laminations tightly held by welded end fingers • Positive ventilation system

Construction of This Dynamically Balanced Armature Reveals New G-E Methods of Building Vital D-c Motor Parts to Give Long, Heavy-duty Service

EVERY General Electric d-c motor armature has *inner* and *outer* protection against damage from abrasion—heat—aging—oil—alkalis—mild acids. Insulation of the Formex wire windings permanently retains its high dielectric strength. It is at least three times tougher, more flexible, and much more resistant to abrasion than conventional enamel. It shows no tendency to become brittle, crack, and lose its toughness on long exposure to heat. And the heavy, baked-in coat of Glyptal base varnish binds the windings into a solid mass that's highly resistant to mechanical injury.

Careful attention to materials and design extends to every vital part of G-E direct-current motors. Built-up commutator; heavy, adjustable brush rigging; Formex wire field coils; and improved bearings—all are built to withstand severe operating conditions.

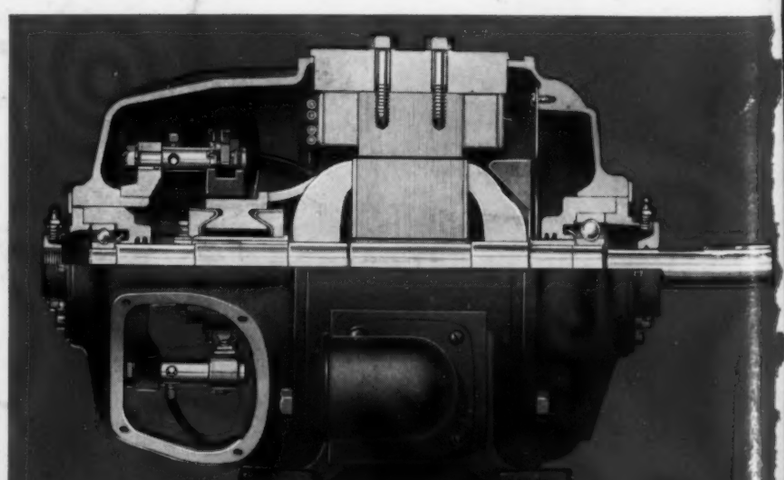
Call or write your G-E office for complete details on this outstanding new motor. And ask for your copy of GEA-1542D. General Electric, Schenectady, N. Y.

GENERAL ELECTRIC

750-72-8398

Note This Motor's New Convenience Features

Reversal without changing any part of frame, fan, or brush rigging—Ventilating fans specially designed for efficient cooling regardless of direction of rotation—Compact assembly—Lower WR^2—Small diameter—Ball- and sleeve-bearing brackets interchangeable on the larger motors.



Sectional view, ball-bearing d-c motor (Type B). Open motors are available with ball or sleeve bearings—in constant-speed ratings from ½ to 60 hp; in adjustable-speed ratings from ½ to 15 hp.